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FY 1979-1983. RESEARCH AND TECHNOLOGY PLAN. PART III. TECHNOLOG--ETC(U)
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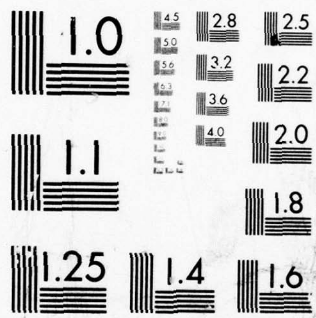

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FY 79-83 RESEARCH AND TECHNOLOGY PLAN

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AIR FORCE MATERIALS LABORATORY

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PART III. TECHNOLOGY PROGRAMS

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AIR FORCE MATERIALS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT - PATTERSON AIR FORCE BASE
OHIO 45433

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INTRODUCTION

In this part of the Research and Technology Plan, the technical details of the AFML program are displayed according to Technical Planning Objective (TPO). The broad, general objectives of each TPO, together with the major Laboratory technical thrusts supporting the objectives are discussed. The detailed goals and technical approaches for each major thrust are presented, and The applicability ~~of the thrusts~~ to the Systems Command development goals, to the Product Divisions' technical needs, and to the user Commands' operational requirements are clearly illustrated. These requirements are the overriding considerations in the Laboratory's selection and prioritization of the major thrusts.

The milestone charts at the end of each TPO section illustrate the points in time when materials technology will be ready for transfer to the various requirements. Decision points are illustrated with triangles ($\triangle$) and transition points with inverted triangles (∇).

With one exception, the TPO's are aligned one to one with the Laboratory 62102F Projects, as follows:

TPO 1 Thermal Protection Materials, Project 2417

TPO 2 Aerospace Structural Materials --

Metallic Structural Materials, Project 2418

and

Nonmetallic Structural Materials, Project 2419

TPO 3 Aerospace Propulsion Materials, Project 2420

TPO 4 Fluids, Lubricant, and Elastomeric Materials, Project 2421

TPO 5 Protective Coatings and Materials, Project 2422

and

TPO 6 Electromagnetic Window and Electronic Materials, Project 2423

TECHNOLOGY PLANNING OBJECTIVE

TPO NUMBER 1 TITLE THERMAL PROTECTION MATERIALS

GENERAL OBJECTIVE AND INVESTMENT STRATEGY:

Provide materials, processesm and supporting technology for thermal protection of systems and componentry which are subject to severe thermal and particle erosive service environments. Major applications are in strategic ballistic and maneuverable reentry vehicles (RV), high mach number (hypersonic) aircraft, tactical missiles, rocket nozzles, and ground support equipment. The identification of erosion due to ice, snow, rain, and dust particles as a threat to reentry body survivability and accuracy, along with the existing severe thermal environment, dictates that the TPO be oriented primarily towards materials and technology that will improve performance and survivability of ballistic and maneuvering reentry vehicles. Investment in the RV materials area is driven by critical performance requirement needs with cost and materials availability as secondary factors. The major areas of emphasis in this TPO will provide materials which have high shape stability during exposure to severe environments that in turn have significant impact on RV nosetip survivability requirements and on RV accuracy. In addition, work in the TPO is designed to provide the technology for major step function improvements in reduced RV material manufacturing costs and in assuring the continued availability of component materials by evaluating and developing suitable substitute/replacement materials. The overall effort is primarily oriented toward nosetips (about 60%) and will continue to stress that area at least through FY 83. The remainder of the effort is devoted to rocket nozzle and heatshield materials. For nosetip applications, development will continue to emphasize shape stable carbon-carbon composites for erosion and ablation environments. The long term objective is for shape stability in severe thermal and erosion environments with a more immediate goal to provide protection to mild weather conditions. Efforts will be maintained to develop alternate materials and processes to produce carbon fibers and fabrics for use in heatshield, nosetip and nozzle materials. Concurrent with the materials development programs are efforts devoted to understanding phenomenology associated with ablation and erosion, development of advanced materials concepts, materials modeling to guide economical materials development and the development of processing models to understand the influence of the process environment on carbon-carbon properties. These programs are designed to provide insight and guidance to materials development. This technology is significant to our strategic forces capability to penetrate the Soviet defenses and destroy objective targets because of its critical influence on accuracy. The shape stability of the nosetip is the major factor in defining circular even probability (CEP) of the reentry vehicle and the erosion, ablation and internal characteristics of the nosetip material are the predominant factor influencing the shape stability of the nosetip. Finally, factors such as producibility and decreased cost are being addressed by manufacturing methods program once satisfactory performance solutions have been achieved.

SPECIFIC GOALS AND TECHNICAL APPROACHES:

Within this TPO there are five major thrusts. Work on Shape Stable Nosetips is concerned with erosion resistant carbon-carbon composites and alternate carbon-carbon composites. In Lightweight Heatshields emphasis is on the development of a low cost carbon fabric as a replacement for rayon based carbon materials which will likely not be available in the future. Modeling and Guidance efforts are devoted to quantifying the effect of composite microstructure on material ablation, erosion and thermo mechanical performance. The thrust on Advanced Materials Concepts is designed to identify and demonstrate the basic materials for future system needs. Carbon-Carbon Processing Science efforts are focused on establishing effects and criteria for the influence of process variables on composite microstructure and performance.

Shape Stable Nosetips

The efforts under this thrust deal mainly with the materials and technology necessary to develop shape stable nosetip materials and/or concepts. The thrust is based on developing carbon-carbon materials to survive a thermal erosive environment specified by mission trajectories map (reentry velocity and reentry angle) for the total service requirement. a quantitative number cannot be determined analytically, major CEP improvements are only possible through the use of predictable, uniform ablating, shape stable nosetip materials. The added requirement for all weather reentry capability has placed increased emphasis on erosion behavior and added strength. These materials also are essential in designs to provide capabilities for survival in a maneuvering reentry system.

Erosion Hardened Carbon-Carbon Composites

The objective of this direction is to develop a high performance carbon-carbon composite with mild weather capability of a RV weather severity index (WSI) rating of 10. Limited work will be done on erosion phenomenon and model assessment to guide the materials development. Three aspects of the composite will be investigated in achieving the WSI rating of 10. These are the metallated matrix, the advanced weave preform, and the advanced reinforcement. Specific milestones include (1) suitable analytical models for guiding improved composite development, (2) special erosion resistant reinforcement materials, and (3) fine weave or soft cure carbon-carbon composites for nosetips.

Alternate Carbon-Carbon Composites

The goal of this direction is to develop an alternate carbon-carbon composite containing a replacement graphite reinforcement and matrix. The program recognizes the future nonavailability of precursor continuous filament rayon yarn for producing graphite yarn and addresses PAN and pitch as possible alternate precursor

fibrous materials. Early phases of the program will exploit efforts on polyacrylonitrile (PAN) and pitch being carried out by industry and other agencies. Specific funded efforts leading to a final candidate material include PAN based yarn and tow development, perform development of low cost constructions, improved process development, and alternate matrix developments. Milestones in the program include (1) dependable tow source, (2) a low cost, high strength, pure graphite yarn or tow, (3) low cost pitch based C/C for AF applications, (4) and manufacturing producibility of selected nosetip composites.

Lightweight Heatshields

This thrust has the goal of developing a replacement, low cost and insulative plastic composite material for RV heatshields. There is a need to replace continuous rayon yarn as a precursor for carbon fabric due to the projected nonavailability of the currently used precursor rayon material. The heatshield is required for advanced mission reentry systems. The program will evaluate and develop carbon fabric including weaving techniques. Major emphasis will be on balanced property carbon fabric and tapewrap cylinder development and optimization. Key decision points will involve questions of (1) whether further improvements in pitch based carbon fabrics are required, (2) if weaving C-yarn is more cost effective than weaving and pyrolyzing PAN fabric, (3) is staple rayon carbon/phenolic a suitable missile heatshield material, (4) which C-fabric exhibits best potential for follow-on, and (5) whether a manufacturing methods program for continuous carbon filament-phenolic heatshields is needed.

Modeling and Guidance

The goal of this thrust is to determine the sensitivity of material microstructure parameters on ablation, thermal structural and particle erosion behavior. These factors have significant influence on predictability and performance of carbon-carbon and carbon/phenolics and their influence on shape stability An understanding of the material surface interaction with the environment will be pursued in the form of mathematical and semi-emperical models. Ablation, coupled ablation/erosion and thermostructural response computer code analysis from the point of view of the materials development will continue. These tools will be used in guiding and optimizing the development of innovative materials concepts and in the performance predictions of recommended material concepts. Specific programs will address erosion and ablation microstructure modeling and evaluation, materials influence on shaping, impact data analysis and high temperature property data and models.

Advanced Materials Concepts

The goal of this thrust is to identify and demonstrate materials concepts for future applications with emphasis on the issue of

reentry vehicle accuracy and erosion resistance. Efforts will include seamless construction advanced reinforced composites to control the contribution of tape wrapped heatshield materials to RV spin, advanced self reinforced carbons, development of new high char and easily processible matrix materials, versatile multidirectional material fabrication and extensive fabrication and screening of materials concepts. One milestone is to evalute adequacy of roll torque performance test evaluation methods while a second is to address whether technology on the new processible matrix materials is ready for transition to the low cost carbon-carbon composite development.

Carbon-Carbon Processing Science

The goal of this thrust is to establish the effects and criteria for the influence of processing variables on composite microstructure. This effort will provide guidance to processing of improved carbon-carbon materials for nosetips and rocket nozzles both of which are critical to strategic missile performance and accuracy. Specific programs include processing modeling feasibility and demonstration, study of the influence of microstructure on performance, and low pressure processing guidance. The major milestones in the program involves an early decision on whether the processing model is ready for nosetip material process application.

RELATED EFFORTS:

Within the reentry community there are several organizations conducting interdependent and complementary programs to develop improved thermal protection materials or systems. SAMSO/ABRES is pursuing advanced development programs in various environmental protective materials and performance predictive approaches necessary for design and evaluation. About two to three million dollars are spent annually to upgrade materials, purchase materials for data generation, and for flight test characterization. These materials are those being developed by the AFML and data produced is of critical use to ABRES. The other sister services are also conducting complementary programs. The current Navy (Naval Surface Weapons Center) long range technology program is approximately $3.5 million and the Army (AMMRC) near term program is about 0.4 million. These two organizations along with the AFML are currently participating in the tri-service Materials Development Coordinating Committee along with ABRES in an effort to insure maximum return on investment is achieved with no duplication.

The ABRES Materials Requirements Definition Program identifies and quantifies specific materials requirements which in turn can be pursued by the tri-services. The AFML also directs manufacturing producibility and supporting efforts to provide the Minuteman SPO with materials which are suitable for selection and engineering development as prototype RV nosetips and heatshields

The process science studies on carbon-carbon materials have been effectively coordinated with the AFOSR and ONR. Basic research

organizations are currently funding the program area at approximately 0.4 million per year.

Coordination is effected with NASA, ERDA/NRA (LASL, Sandia and Y-12) and with DNA. Coordination is also effected with principal RV contractors, i.e., McDonnell-Douglas, General Electric, AVCO, and Lockheed Missiles. IRAD efforts of these contractors are carefully monitored, evaluated, and exploited in succeeding government contracts. Recently, RV production programs have diminished, and IRAD efforts have been seriously eroded.

The main vehicle for the evaluation of the products produced will be SAMSO ABRES flight test programs such as MSV, ANT, TDV, and SDV. Continuing flight test by SAMSO Minuteman is also underway.

REQUIREMENTS

Efforts under this TPO primarily impact the Strategic Offense area, specifically reentry vehicles with significant technology transfer to the rocket nozzle activity in TPO-5. Close liaison is maintained with the ABRES and Minuteman programs. At SAMSO, there are three collocated AFML professionals. Efforts impact improved performance needs, survivability and accuracy, the latter through ensuring predictable and uniform ablation behavior and shape retention.

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
1	TPG	Strategic Offense	Critical
2	TPG	Strategic Defense	Desirable
3	TPG	Technology Development	Desirable
4	TN-SAMSO-AFML-67-24	Low Recession, Shape Stable Carbonaceous Nosetip Materials	Significant
5	TN-SAMSO-AFML-67-25	Processable High Temperature Resins for Ablative Composites	Desirable
6	TN-SAMSO-AFML-68-22	Influence of Dust, Rain, and/or Ice on Reentry Vehicle Materials Performance	Critical
7	AFSC Development Goal SO-2	Penetrate Soviet Defenses	Significant
8	AFSC Development Goal SO-3	Destroy Objective Targets	Significant
9	TN-SAMSO-AFML-71-76	Development of Resinous Composite Heatshields for Advanced Hardened Reentry Vehicles	Significant
10	TN-SAMSO-AFML-71-79	Thermochemical Properties for Carbon Heatshield Materials	Significant
11	TN-SAMSO-AFML-74-21	Low Recession Shape Stable Carbon-Carbon Nosetip Materials	Critical
12	TN-SAMSO-AFML-76-03	Carbon-Carbon Materials for Rocket Nozzle Applications	Desirable

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
13	TN-SAMSO-AFML-76-28	Graphite and Carbon-Carbon Property Data	Significant
14	TN-SAMSO-AFML-76-30	Carbon-Carbon Reinforcements	Significant

AFML TPO-1 THERMAL PROTECTION MATERIALS

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
SHAPE STABLE NOSETIPS	62102F	2417	396	497	757	933	904	1250	1050
Erosion Hardened Carbon-Carbon Composites			3	3	3	3	3	3	3
					1	2 3			1-8, 11, 13, 14
	63311F		(498)	(655)	(600)	(600)			
			1	1	1	1			
	78011F		110					1000	2000
								1	1
SHAPE STABLE NOSETIPS	62102F	2417	402	354	288	375	300	200	300
Alternate Carbon-Carbon Composites			2	2	2	2	2	2	2
				1 2	3 4				
	63311F		(552)	(365)	(400)	(400)			
			1	1	1	1			
	20133G		(2000)						1-8, 11, 13, 14
			1						
	78011F			200		300			

AFML TPO-1 THERMAL PROTECTION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LIGHT WEIGHT HEAT SHIELDS	62102F 2417	532 2	650 2	485 2	400 2	300 2	400 2	400 2
		1	2 3	4 5				1-3, 7-10
	63311F	(120)	0	(161)	(171)			
	78011F		200 1	300 1		300 1		
MODELING AND GUIDANCE	61101F ILIR	60	100					
	62102F 2417	255 3	213 2	247 2	240 3	270 3	150 3	150 3
								1-8, 11, 13, 14

AFML TPO-1 THERMAL PROTECTION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE	PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
ADVANCED MATERIALS CONCEPTS	61101F	ILIR					100 1	100 1	100 1
	62102F	2417	130 2	206 2 1	149 2	167 2	216 2	250 2	300 2 1-8, 11, 13, 14
CARBON-CARBON PROCESSING SCIENCE	61101F	ILIR			100	100			
	62102F	2417	15 1	90 1	104 1 1	305 1	240 1	150 1	200 1 1-5, 7,8, 11-14

AFML TPO-1 THERMAL PROTECTION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
TOTALS:								
FUNDS								
61101F		60	100	100	100	100	100	100
62102F		1730	2010/200	2030/200	2150/200	2230/150	2400/200	2550/250
78011F		110	400	300	300	300	1000	2000
PE 62102F 06DS		1000	910	675	685	740	780	800
Non-Add								
SAMSO 20133G		(2000)						
ABRES 63311F		(1170)	(1020)	(1161)	(1171)			
TOTAL TPO FUNDING		6070	4440/200	4266/200	4406/200	3370/150	4280/200	5450/250
MANPOWER								
S, E & T Direct MY		16	15	15	15	15	15	15

TECHNOLOGY PLANNING OBJECTIVE

TPO NUMBER 2 TITLE AEROSPACE STRUCTURAL MATERIALS

GENERAL OBJECTIVE AND INVESTMENT STRATEGY:

Provide reliable materials and processes with optimum combinations of properties from cryogenic temperatures to 1200°F for use in aerospace structural applications. Major applications are in subsonic and supersonic aircraft, missiles, and spacecraft. The objective encompasses the development of alloys having high toughness/density ratios, new or improved low cost organic matrix composites having improved durability and high strength/density and stiffness/density ratios, improved processing and joining techniques for metals and composites, and nondestructive measurement, evaluation, and inspection techniques essential to a high degree of quality assurance and structural integrity. It includes the development of behavioral methods of analysis and their experimental validation under anticipated service loads and environments, as well as the determination of appropriate design data necessary to predict performance levels and capabilities with high confidence.

The Investment Strategy of the area for the FY79 and beyond time frame involves driving towards the goals of Acquisition Cost Reduction and Cost of Ownership Reduction in both composites and metallic materials. The metals area includes thrusts emphasizing cost affordable titanium structures, and both the metals and the composites areas will have continued major thrusts in improved structural integrity and nondestructive evaluation. A new thrust in this TPO is that of computer aided manufacturing, and the funds associated with this thrust will increase significantly over ensuing years. Overall, during the five year period covered by this plan, the funds devoted to this TPO will increase slightly. Some specific areas where the TPO impacts in a significant fashion include strategic offense development goals concerned with penetrating Soviet defense, destroying objective targets, and reconstituting the strategic attack force; strategic defense goals of providing the information to respond to a bomber/bomber-launched missile attack, and providing an atmospheric interdiction capability; tactical warfare development goals on providing surveillance of airborne targets, eliminating airborne threats, neutralizing fixed surface targets, and neutralizing mobile surface targets; reconnaissance development goal on collection of data and information; and the airlift forces goals of airlift of unit equipment and personnel to areas where the US becomes engaged in a conflict - requirements for Europe are the most stringent, and providing intra-theater transportation for goods and personnel which is not provided by surface transportation. The TPO impacts the AFSC policy goal on life cycle cost in a significant manner.

SPECIFIC GOALS AND TECHNICAL APPROACHES:

There are twenty-one thrusts within this TPO, covering both metallic and nonmetallic structural materials.

In the metals areas, Improved Structural Integrity is intended to provide approaches whereby new safety, durability, and life management requirements can be implemented with no increase in cost. Acquisition Cost Reduction is attempting to reduce the acquisition cost of metallic airframes by 20-30% without incurring a weight penalty or increasing maintenance costs. Cost of Ownership Reduction has the goal of a 15-20% reduction in the amount of AFLC funds expended on the maintenance of airframes. Expanded Performance assures the availability of the metals technology required for future high performance aircraft. Metal and Alloys, Metallic Materials Behavior, and Joining and Processing, cover the technology base for the metals area, and address the technology for low cost titanium, high performance alloys, fatigue and fracture, chemical/environmental effects, impact/dynamic loading, analytical process modeling, enhanced materials utilization and processing efficiency, improved service life of metals, improved durability, and predictable, reliable structural behavior. In the nonmetals area, the Advanced Composite Materials Development thrust is developing low cost, moisture resistant materials with 350-600°F capability while also developing low cost processability. The Advanced Fabrication thrust, which has the goal of reduced fabrication costs for composite components, includes work on low cost tooling, low cost manufacturing, and stresses the design/manufacturing interface to reduce acquisition cost. The goal of the Production Confidence thrust for composites is to develop integrated and economical methods and assembly procedures for quantity production of composite structures, and to develop a broad industrial production base. In Advanced Composite Materials Durability there is work on developing alternate design/manufacturing concepts to aluminum honeycomb sandwich, establishing chemical composition and processing specifications with 100% acceptance by industry, developing a capability to predict composite laminate static and fatigue strength, and establishing defect accept/reject criteria to reduce repair and rejection rates. Adhesive Bondings, Nonmetallic Composites and Polymers for Structural Materials provide the nonmetal technology base thrusts in the areas of improved processability, durability, and performance of adhesives and composites; failure mechanisms and durability roles in mechanics of composites; and new resin polymer systems and self reinforcing polymers.

Thrusts covering both metals and nonmetals are included in the area of nondestructive evaluation: NDE of Fastened Joints has the objective of developing nondestructive evaluation methods of detecting outer layer and interior layer cracks and determining hole quality in composite materials. Field NDE Relia-

bility Improvements is concerned with efforts on ultrasonic methods, liquid penetrants and sensitivity/capability definition. Composites In-Service Inspection Methods is devoted to developing near term field capability to detect service induced flaws of 1/4 square inch and to develop a broad base structural NDE capability for water degradation, FOD, etc. Adhesive Bond Evaluation is concerned with the establishment of NDE methods that could be used to determine pre-bonded surface quality and identify bondline flaws. NDE of Complex Shapes covers computer-aided methods for low cost, high quality inspection of complex, near-net-shape engine and airframe components. Energy-Structures Interactions provides the NDE technology base in the areas of quantitative flaw characterization, NDE of advanced materials and quantitative NDE for surface flaws.

A major thrust in this TPO is that of Computer Aided Manufacturing. It focuses on the disciplined application of integrated computer aided manufacturing systems to the major functions of manufacturing, with the overall goal of increased productivity and flexibility in the manufacturing and production of defense-related material. Major areas of emphasis include manufacturing architecture, fabrication, data base/data automation, design manufacturing interaction, planning and group technology, manufacturing control and external interfaces, assembly, simulation modeling and operations research, materials handling and storage, and test inspection and evaluation.

Improved Structural Integrity

This thrust is based upon the use of improved processes and materials control methods, analysis techniques, test procedures, and a more sophisticated data base. The directions, or efforts within the thrust will develop criteria for material quality to allow the proper specification of materials for production and use. This thrust has a significant impact on the policy goal for life cycle cost as it addresses major improvements in life cycle management needs at current cost levels. This work on airframe durability has major impact on advanced system design and materials performance for systems to provide atmospheric threat interdiction capability, to acquire fixed surface targets, to acquire mobile surface targets, and for both long haul and intra-theater airlift. In the area of reconstituting the strategic attack force it has significant impact because of its influence on airframe integrity.

Initial Quality (Holes) - The goal of this direction is to provide a method for quantifying structural fastener hole quality, and to optimize hole quality vs. life vs. cost. The approach involves characterizing typical production hole quality and hole inspection techniques, quantifying the effects of various types and sizes of defects in terms of apparent initial crack size, validating the 20-25% cost savings avail-

able by tuning the processing and inspection requirements and quantitatively determine the cost and integrity advantages of advanced fastener systems. Key decision points involve (1) determining whether current procedures are sufficient to allow cost trades or whether it is necessary to improve current drilling or inspection techniques and (2) specific fastener types to be included in advanced fastener system variables activity.

Materials Properties and Control - This effort will obtain comparative evaluation and engineering design data on newly developed structural materials, along with existing materials in new forms or produced by new processes, as they become available for use in Air Force weapon systems. It will develop an affordable crack growth test for quality control, a standardized test method for design crack growth data generation, reduce scatter in Ti-6 Al-4-V fatigue related properties through improved processing and generate and disseminate data on new materials and product forms. Key decision points involve: (1) deciding whether to submit to DOD or AMS authorities a proposed specification for the processing of Ti-6 Al-4 V alloy for control of fatigue scatter and (2) deciding whether a new standard for a crack growth test will be a government or industry standard and specific material selection for FY80 data generation program.

Acquisition Cost Reduction

This thrust includes efforts involving aluminum and titanium alloys, steels, low cost machining and bonded structures. The goal is a 20-30% reduction in the acquisition cost of metallic airframes, and the approach involves exploratory, advanced development, and manufacturing technology efforts aimed at materials, processes, and fabrication techniques that will lead to low cost finished structural components. The goal of 20-30% reduction is a critical factor in the life cycle cost goal. In addition, reduction in cost of the advanced materials being worked in this thrust have significant impact on their potential for use in advanced systems such as the FOI for the atmospheric threat interdiction capability and the ATF type system for the tactical roles of acquiring fixed and mobile targets.

Aluminum Adhesive Bonded Structure - This direction will develop the technology for the broadest application of adhesive bonding to aluminum primary structure including cost and weight savings and improved predictability/reliability. The work will determine the long term durability of new surface treatments for bonded joints, the effects of bondline defects, and will validate the structural integrity of bonded joints in full scale tests. Key decision points are: (1) select design concept for an advanced development program and initiate fabrication, (2) implement results in AMST and A-10, and (3) define content and hardware of production integration program.

Applications of AF-1410 for Cost Reduction - The goal will be to demonstrate cost savings potential of substituting AF 1410 for Ti-6Al-4V. Efforts will continue on production feasibility demonstration for large heats and product forms and on the machinability data - structural verification activity. The decision point for the effort involves incorporation of AF1410 in an aircraft demonstration program.

Aluminum Castings - The goal is to demonstrate a minimum of 30% acquisition cost savings with no attendant weight penalty or increase in maintenance costs for cast aluminum structure. Emphasis will be placed on casting technology and the impact of casting tooling on design allowable testing. Key decision points are: (1) process technology transition by disclosure through process and vendor qualification specifications and (2) transition to systems.

Built-Up Low Cost Advanced Titanium Structure - A specific goal of this effort is to demonstrate capability to produce titanium built-up structures at a cost approaching that of conventional aluminum structure and to allow achievement of significant weight reductions through use of affordable titanium structure. The approaches involve the use of improved fabrication techniques such as superplastic forming, diffusion bonding, cold-formable sheet material, and advanced joining processes It includes the development of a broader design allowable and structural verification base, along with improved inspection and repair procedures. The key decision points involve (1) production commitment of F-15 engine fairing, (2) proceed with flight test on YC-15 - commit flaps to production if successful, (3) demonstrate parts for Phase II, (4) specific alloy selection, (5) contracting approach for tooling program, (6) need for scale up program, (7) select key technologies for additional development, and (8) approval and baseline candidate selection for ATF related 6.3 program.

Thick Section Titanium - With the goal of demonstrating 40-60% cost reduction for thick section titanium airframe applications, the approaches in this effort include powder production, compaction in near net and large titanium parts, diffusion bonding, welding, and casting. Key decision points involve: (1) determining the limits of NDE for inspecting net shape parts, (2) advanced die material and lubricant selection, (3) decision to pursue computerized diffusion bonding opportunity and (4) approach for advanced programs.

Metal Removal - The goal of this direction is to achieve a total machining cost reduction of 50% on near net shape parts, to cut reject rate and set up costs by 50% and to cut run time by 50%. Specific efforts include evaluation of innovative tools and methods, economics modeling application and characterization, intelligent adaptive control and on-line inspection and high speed machining. Key decision points are (1) on line inspection and monitoring input from ARPA program, (2) specific high speed aluminum machining approach and (3) content of steel high speed machining activity.

Cost of Ownership Reduction

The goal of this thrust is to provide the opportunity for a reduction in the amount of AFLC funds expended on the maintenance of metallic airframes. The directions being pursued under this thrust include corrosion control, mechanical fasteners, metallic structure repair, reduced cycle cost landing gears, and crack growth resistant powder aluminum. The policy goal of life cycle cost is significantly addressed in this thrust with its goal of a 15-20% reduction in cost of ownership. While this has application to all systems it would particularly impact goals on airlift, bomber, and fighter aircraft.

Corrosion Control - This direction will provide the capability for a significant reduction in corrosion control maintenance costs. It will develop advanced corrosion inhibitors, develop prediction procedures, and provide coatings for protection of DU materials. Key decision points are: (1) select approach for evaluation of aluminum protected main landing gear, (2) define application for hot spot inhibitors and (3) select an aircraft for application of an advanced data base to corrosion prediction.

Mechanical Fasteners - This direction will define the limits of benefits gained through use of advanced fatigue improvement. It will address fatigue life improvement, hole conditioning technology and hole generation technology. Decision points involve: (1) selection of an advanced fastener system for data generation, (2) assess payoff of high speed drilling, (3) assess the depth of data base required for new fastener materials, and (4) develop priorities on types and sizes based on industry input.

Metallic Structure Repair - The goal of this direction is to develop low cost techniques to be used by AFLC for repair and maintenance of metallic airframes. It includes improved honeycomb rebuilding, bonded structure repair for both primary and secondary structures, and the development of advanced generic repair techniques. Key decision points involve the determination of items to be pursued, (2) selection of hardware for manufacturing validation, (3) approach for generic repair and (4) approach for implementation by ALC's.

Reduced Life Cycle Cost Landing Gear - By exploiting the advantages of titanium alloys and composites, this effort will design, fabricate, and fatigue and flight test a reduced life cycle cost landing gear concept. The intent is to take advantage of new materials and processing technologies to gain confidence for their application to new systems. The program will make use of advanced titanium joining methods and advanced composite landing gear component development. Key decision points are (1) the selection of the bogie beam design and (2) definition of an advanced gear program.

Expanded Performance

The general goal of this thrust is to improve the performance of existing alloys and components. It exploits technological advances in alloy development and processing, and it is particularly applicable to cases where there is currently a severe problem because a particular property of an alloy or alloy system prevents the full utilization of its other beneficial properties. This goal primarily addresses the needs for future systems and would have impact on the FOI for atmospheric threat interdiction and the ATF for fixed and mobile surface target neutralization.

Crack Growth Resistant Powder Aluminum Alloy - This effort is directed towards an improvement in the fatigue crack growth rate behavior of aluminum alloys. With the goal of a 20% increase in the usable strength of aluminum alloy products, it is using a powder metallurgy approach to develop an order of magnitude improvement in fatigue crack growth rate behavior without a decrease in other properties. The key decision point concerns the need and approach for weldability evaluation.

Metals and Alloys

The goals of this thrust are to develop Ti alloys/microstructures giving improved properties and greater cost reduction when used in low cost processes as super plastic forming, to provide the technology base to develop aluminum alloys with an order of magnitude fatigue life improvement over current alloys, with no loss in strength or corrosion resistance, to develop an aluminum alloy for extended use at 450°F, and to develop a fatigue resistant titanium alloy with 20% improved temperature capability. The general approach involves determining the microstructural factors controlling properties in the various alloy systems. Decision points involve: (1) alloy selection for scale up of powder aluminum, (2) selecting a 450°F aluminum alloy candidate composition and (3) question of hot salt stress corrosion in titanium. This goal primarily addresses the needs for future systems and would have impact on the FOI for atmospheric threat interdiction and the ATF for fixed and mobile surface target neutralization.

Metallic Materials Behavior

This thrust will develop improved procedures for predicting the fatigue performance, fracture behavior, fracture toughness levels, environmental durability, impact and dynamic loading and integrity of structural materials. The approach is based on improved materials control methods, analysis techniques, test procedures, and a more sophisticated data base. It will develop refinements in the methods and analyses used for predicting the response of materials and structural components to impact and impulsive loading conditions, with particular emphasis on the response of materials to foreign object damage. It will also investigate methods for predicting and preventing

corrosion effects on structural materials and will develop inhibitor systems for structural alloys. This thrust has a significant impact on the policy goal for life cycle cost as it addresses major improvements in life cycle management needs at current cost levels. This work on airframe durability has major impact on advanced system design and materials performance for systems to provide atmospheric threat interdiction capability, to acquire fixed surface targets, to acquire mobile surface targets, and for both long haul and intratheater airlift. In the area of reconstituting the strategic attack force it has significant impact because of its influence on airframe integrity.

Joining and Processing

This thrust addresses the technology base for improved joining and processing techniques. This thrust primarily addresses the policy goal of life cycle cost through its attack on reduced processing costs and extended service life through improved repair procedures. It also applies to development goals concerned with lightweight and less expensive materials and built-up structures.

Analytical Process Modeling - This effort will develop lower cost, energy efficient processing techniques; integrated CAD/CAM processing; and improved component durability. Included are programs in material workability and process modeling for sheet metal forming. Decision points are: (1) determine the ability to predict experimental forming limit, (2) determine cost effective approach to hard to handle workability problems and (3) determine readiness of process models to handle more complex shaping operations and microstructural control.

Enhanced Material Utilization and Conservation - This direction addresses net shape processing, low cost built-up structures, and new materials by melt extraction and rapid solidification. The approaches include the use of prealloyed powders for controlled homogeneity and the more efficient achievement of net shape, the establishment of welding and brazing techniques to permit assembly of lower cost airframe and engine components, and the development of prealloyed powders. Decision points are: (1) selection of the processing limits for new rapidly solidified materials and (2) decision on readiness of joining methods.

Adhesive Bonding

This thrust provides the technology base for improved durability, predictable structural behavior, and quality assurance of adhesively bonded joints. Efforts on low cost procedures for increased durability of bonded joints involve the development of surface preparation methods, adhesives, and bonding processes that will lead to joints having improved resistance to degradation caused by exposure to corrosive environments. Programs aimed at predictable structural behavior for adhesive bonding

use fatigue and crack propagation studies to develop fracture toughness and inspection criteria for structural bonded joints. In addition, the thrust emphasizes the quality assurance aspects of adhesives by establishing acceptance criteria for adhesives, developing cure monitoring techniques, and acquiring a knowledge of chemical bonding phenomena and bond failure mechanisms and how they apply to improved structural reliability. This thrust provides improved bonded joint technology which will lead to lower cost structure assembly for systems such as RPV's and better quality bonding of advanced aircraft systems structure. It impacts development goals relating to those type systems.

Advanced Composite Materials Development

This thrust emphasizes the development of composite materials that have higher temperature capabilities and good durability in terms of moisture resistance. It includes the development of low cost processing techniques for the composite materials themselves, along with processing methods for new low cost materials such as self-reinforced polymers. The specific goals are a temperature capability of 350-600^{o}F and a 20-30% lower processing cost. Efforts include determination of the specific requirements of surface interface chemistry, fiber treatments, and resin chemistry to resist moisture degradation; development of polymers and transitioning to resin systems with improved performance in temperature/moisture resistance and competitive cost; and development of low flow, low pressure resins for reduced processing costs. These developments include acetylene terminated chemistry, high vinyl modified epoxies, high temperature thermoplastics and self-reinforcing polymers. Advanced composite materials are significant to many future systems options due to the fact that they provide low cost, lightweight, aeroelastic tailoring and many other properties critical to the advanced designs. Included in those systems would be those covered by developmental goals on acquiring fixed and mobile surface targets, airlift intra-theater and longer haul needs, FOI for atmospheric threat interdiction, and strategic systems such as advanced air launched missiles for penetrating Soviet defenses and destroying targets.

Advanced Fabrication

The goals of this thrust are a 15-60% reduction in the non-recurring and recurring costs of manufacturing and processing and a 15-25% reduction in acquisition costs relating to aluminum construction. The thrust covers developments in low cost tooling and manufacturing concepts; development directed at self contained and non-autoclave tools; thermoexpansion molding; low cost cutting, machining and drilling; development of manufacturing and tooling methods for thermoplastics; the manufacturing/design interface; and low cost wing/fuselage manufacturing techniques. Key decision points are: (1) critical design review of major critical components, (2) completion of demonstration of all critical components for an all composite aircraft. This

thrust provides the basic production capability for advanced composite materials and as such has a major impact on the same development goals cited in the thrust on Advanced Composite Materials development. It also impacts the policy goal on life cycle cost in a significant manner because of the impact on cost of system production.

Production Confidence

The goal of this thrust is to develop an integrated economical method for production and assembly of composite structure and the establishment of a broad production base to allow for a 50% by weight composite aircraft structure. It involves acquiring production experience with multiple unit fabrication of composite structures, along with service experience with structures on aircraft in the field. It includes programs aimed at the delineation of the manufacturing operations that would be necessary in a full scale, integrated composite aircraft facility. Specific approaches include determination of the high cost centers of fabrication and assembly of composite structures; development of integrated techniques for the lay-up, curing and assembly of composite structures; and the establishment of a broad industrial confidence base for the production of composite structures through a fabrication guide, build to print and production/service experience.

This thrust provides the basic production capability for advanced composite materials and as such has a major impact on the same development goals cited in the thrust on Advanced Composite Materials development. It also impacts the policy goal on life cycle cost in a significant manner because of the impact on cost of system production.

Advanced Composite Materials Durability

This thrust includes concerns with improved quality control, reduced O&S costs, and failure prediction and acceptance criteria. The improved quality control goal is to develop chemical composition and processing specifications for composite materials and to achieve full acceptance by industry and the Air Force. It includes the formulation of acceptance criteria for the chemical compositions of matrix resins and adhesives, and the development of processing control criteria. The reduced O&S costs goal is to develop field usable NDE methods for moisture and strength measurement, holes and edges inspection, and in-service structural monitoring. It includes alternate manufacturing concepts to aluminum honeycomb sandwich. The goal of the failure prediction and acceptance criteria effort will be to develop 100% capability to predict laminate strength. The key decision points are: (1) availability of adequate resin data for specifications, (2) skin stabilization with no aluminum honeycomb demonstrated, (3) manufacturing processes for skin stabilization with no aluminum honeycomb demonstrated. This thrust addresses the serviceability of Advanced Composite Materials and thus impacts the basic development goals cited in

the materials thrusts on those materials. In addition it impacts the policy goal on life cycle cost due to its goal of reduced O&S costs.

Nonmetallic Composites

In providing the technology base for nonmetallic composites, this thrust will develop composite materials having significantly increased resistance to moisture-induced properties degradation. It will also develop composite materials with improved processability to allow for increased flexibility in manufacturing. This involves increased prepreg life at room temperatures; easy processing, low temperature, low pressure-low flow cures; and more reproducible composite properties via controlled processing. In the area of increased performance, the goals are the development of self-reinforcing polymers having high strength/modulus and the development of oxidation resistant graphite reinforced or amorphous metal reinforced composites. Also included in the thrust are efforts on the mechanics of composites with the goals of defining failure modes and mechanisms and developing analytical and experimental methods for predicting life and environmental effects under real life load conditions. Milestones involve: (1) deciding whether self-reinforced polymers have shown sufficient promise to justify mechanics program in the area, and (2) deciding whether failure mechanisms have been sufficiently established to justify micro-mechanics modeling. Advanced composite materials are significant to many future systems options due to the fact that they can provide low cost, lightweight, aeroelastic tailoring and many other properties critical to the advanced designs. Included in those systems would be those covered by developmental goals on neutralizing fixed and mobile surface targets, airlift intra-theater and longer haul needs, FOI for atmospheric threat interdiction, and strategic systems such as advanced air launched missiles for penetrating Soviet defenses and destroying targets.

Polymers for Structural Materials

This thrust addresses resin technology for composite matrix materials and adhesives. The goal is to provide new polymer compositions and approaches to their processing to allow the development of processable, moisture resistant resin systems with improved mechanical behavior at relatively low cost. It includes the establishment of a technology base for the development of self-reinforcing polymers for structural applications. The approaches will focus on the synthesis, characterization and evaluation of new polymer systems, as well as on research to elucidate the structure-property correlations needed to guide the molecular tailoring and processing of new high performance resins. The behavior of the new materials when exposed to temperature, stress, and moisture will be investigated. Key decision points are: (1) selection of candidate materials and approaches from those emerging from the program, and (2) decision for follow-on development of self-reinforced polymers.

Advanced composite materials are significant to many future systems options due to the fact that they can provide low cost, lightweight, aeroelastic tailoring and many other properties critical to the advanced designs. Included in those systems would be those covered by developmental goals on neutralizing fixed and mobile surface targets, airlift intratheater and longer haul needs. FOI for atmospheric threat interdiction, and strategic systems such as advanced air launched missiles for penetrating Soviet defenses and destroying targets.

NDE of Fastened Joints

The goals of this thrust are to develop methods for the detection of cracks out of holes in outer layer and interior layers with the fastener installed and to develop adequate NDE capabilities for determining hole quality. Specific efforts include development of an advanced producible and field ready ultrasonic scanner for outer layer inspection producibility, advanced eddy current system for interior layer inspection producibility, prototype device development, process control relaxation for cost reduction, and NDE of taperlock fasteners. The key decision points are: (1) assessment of critical NDE quality parameters to determine the need for improved NDE methods, (2) determination of the cost effectiveness potential of the semi-automatic ultrasonic Roto Scanner system for Air Force wide utilization, and (3) determination of the potential of multi-frequency eddy current techniques for detecting interior layer defects in multilayer structures in service. This thrust impacts the development goals on aircraft systems including those for bombers, fighters and airlift vehicles. The major area of impact is in system integrity and O&S costs.

Field NDE Reliability Improvement

This thrust will develop improved ultrasonic system equipment, components and methods for field use, and improved capabilities, standards and specifications for the service use of NDE technology. It involves goals of developing qualification criteria and specification data and penetrant standards as well as establishing structure/specimen inspection correlations and analytical procedures for AFLC data base. Specific efforts include improved penetrant evaluation criteria and depot/field capability evaluation and data analysis. Decision points are: (1) establish readiness of improved ultrasonic equipment for overhaul environment, (2) provisions to be developed and incorporated in revised penetrant qualification specification. This thrust impacts the development goals on aircraft systems including those for bombers, fighters and airlift vehicles. The major area of impact is in system integrity and O&S costs.

Composites in Service Inspection Methods

The goal of this thrust is to develop near term capability to detect service induced flaws ($1/4 in^2$) and a broad base structural degradation NDE capability for water, FOD, etc. It

includes engineering design definition for in service flaw detection, system and in service inspection system capability/producibility demonstration and advanced development. Specific areas include in service structural monitoring, hole drilling, cutting and edge inspection, moisture measurements, and internal damage measurements.

Key decision points involve establishing: (1) technology availability for optimization of a method for making on-site moisture measurements, (2) availability of "effects-of-defects" information sufficient to initiate comprehensive in-service/environmental/real time composite structure evaluation program, and (3) technology availability to allow development of an NDE system to measure composite strength. This thrust impacts the Advanced Composite Materials thrust and thus has impact on the same development goals as cited under that thrust.

Adhesive Bond Evaluation

The goals are to develop pre-bonded surface quality NDE methods and flaw identification for bondlines. Specific programs include development of improved flaw measurement capability and surface condition measurement methods. The key decision points are to establish: (1) the availability of sufficient technology for characterization of flaws and bond strength measuring techniques. This thrust defines techniques for evaluation of adhesive bonds and thus has direct impact on the thrust on Adhesive Bonding and through it the systems development goals cited there.

NDE of Complex Shapes

This thrust will develop computer aided methods for the high quality production and depot inspection of complex shapes such as airframe forgings and near-net engine components such as blades and bearings; the inspection and dimensional checking of complex shaped components. Specific efforts include metrology for engine bearings, metrology for blades, rocket motor nozzle NDE methods for production, and airframe crack growth inspection. Key decision points involve: (1) determining requirement for automatic composite fan blade inspection methods, (2) determining the requirement for computer automated inspection system for production, and (3) determining MX nozzle inspection program needs. This goal impacts other thrusts in the airframe area as well as several in TPO 3 on propulsion technology. It has direct impact on development goals for advanced aircraft through its relationship to those development goals.

Energy-Structures Interactions

One of the goals of the NDE technology covered by this thrust is to establish a quantitative NDE capability for the location and characterization of material defects anomalies and residual stress fields. It involves the development of reliable, re-

producible, sensitive quantitative ultrasonic techniques, and the establishment of the methodology of signal acquisition and processing required to extract the information needed in combination with accept/reject criteria. A second goal of the thrust is to develop approaches for the nondestructive evaluation of the quality of advanced materials including adhesive bonds, ceramics and composites. A third goal concerns the NDE characterization of small, tight surface flaws. Specific efforts include work on new transducer concepts, improved ultrasonic equipment, advanced signal acquisition methods, signal processing technology, advanced approaches for measuring strength of adhesive bonds, and measurement of moisture strength properties. This goal provides the technology for the NDE thrusts discussed above and as such has impact on various development goals through its relationship to those thrusts.

Computer Aided Manufacturing

In the past, developments in the use of the computer as an aid to manufacturing have proceeded in a modular, disjointed fashion resulting in a proliferation of computer software and hardware that has in many cases tended to aggravate problems in manufacturing, rather than easing them. This thrust provides the basis for a long term program aimed at the disciplined application of integrated computer aided manufacturing systems to the major functions of manufacturing. The program will include consideration of all the functions that must be performed in order to make a product, and it has the ultimate goal of increasing industrial productivity and flexibility in the manufacturing and production of defense related material. Specific activities will include manufacturing architecture with emphasis in generic architecture, analytic tools and architecture transition; fabrication with emphasis in sheet metal technology, transition and demonstration; data base/data automation with attention to requirements definition, transition and system development and demonstration; design manufacturing interaction including design architecture, geometric modeling and planning/design interaction; planning and group technology with emphasis in manufacturing economics, part characterization code development, material property modeling and process planning; manufacturing control and external interfaces in the areas of job shop control, material management and external interface; assembly including initial assembly cell technology, assembly cell transition and assembly demonstration; simulation, modeling and operations research in modeling technology and analytic tool transition; material handling and storage covering those factors and plant layout; and test, inspection and evaluation including quality assurance.

RELATED EFFORTS:

Materials Development and Processing: Development of increased toughness, fatigue endurance and corrosion resistance with static strength retention is featured in most related

efforts by DOD and NASA groups. Navy programs have emphasized improved clad 7050 aluminum, 6Al-4V-titanium, and medium strength, high nickel steels, with a new, additional emphasis on high strength-to-weight structural approaches to meet VTOL design requirements. Reduction of titanium embrittlement problems through a better understanding of mechanisms is also underway. Interest in composites is high, with the Army and NASA mostly emphasizing applications and the Navy also working, in addition to applications, on development of a 450°F organic-matrix material, reduction of property scatter through tighter process controls, and investigation of new ideas in metal-matrix composites. NASA is conducting a series of preliminary design application studies of the potential of advanced composites in thin-wall space structures, and is considering composites in primary structure trade-offs for the Space Shuttle. NASA is conducting some work on improved joining techniques for B/Al for Space Shuttle components, as is General Dynamics/Convair and AVCO Corporation under IRAD support. Army and Navy efforts are emphasizing the solution of steel welding problems. A Navy program is underway to develop a 450°F adhesive. Another is investigating improved designs for structural adhesively bonded joints. The Army is conducting extensive work on the application of lower cost metals, such as electro-slag remelted steel, as a substitute for the much more expensive dual-hardness steel in both parasitic and structural armor.

Materials Behavior and Characterization: Both DOD and NASA groups are actively working with a multitude of individual programs on many facets of the fatigue and fracture area, and numerous conferences, symposia and coordination meetings in recent years have been effective in planning and conducting many complementary programs. Principal emphasis in NASA is given to advancements in fracture toughness and crack propagation test methods, and associated data reduction techniques, to support fracture mechanics analysis. In addition, leading work is underway to produce crack growth rate prediction capabilities in structures incorporating typical disturbances such as fastener joints, stiffeners, section changes, other cracks, etc. The development of a "unified fatigue model", with which to predict structural fatigue lives under arbitrary environmental, loading and design detail conditions, is also being pursued. The Navy is doing leading work on development of fracture criteria for structural materials of interest for Navy surface and air vehicles. The approach is to develop guidelines for selecting the best material for given structural conditions, based on required strength, environment, structural configuration, etc. A specialized data bank is being accumulated for aluminum, steel, titanium and metal matrix composites. The USAF AFFDL is conducting an extensive fracture and fatigue program to establish improved crack growth rate predictions for structures, and for accurate fatigue failure predictions based on an increased understanding of the influences of various approaches to constructing loading and environment test spectra.

NASA and Navy programs on structural reliability are generally oriented towards the development of specific applications experience using the analytical methodology developed by USAF AFML programs under this TPO. In addition, several programs throughout the above agencies and in USAF laboratories (AFFDL, AFML) are underway to extend the technology base in the statistical mathematics aspects of the area. The AFFDL is also investigating alternate approaches to reliability analysis, in addition to efforts aimed at extending the existing procedures to problems of practical application.

In the area of NDE, all DOD services and ARPA, as well as NASA, are conducting broad-based programs of equivalent or lesser size; however, in each case, investigations are highly oriented to problems unique to and of most concern to the individual agency missions. Thus, generically similar problems are frequently addressed from alternate viewpoints. Cross applications of results are constantly promoted through joint service coordinating activities, joint programs, conferences and symposia.

The integrated computer aided manufacturing program is the only activity of its type in this country.

REQUIREMENTS:

This TPO deals with the development of structural materials and related processes, methodologies and capabilities which contribute to increased structural systems performance levels and durabilities, greater integrity, reliability and survivability, and to lower acquisition and O&M costs. This TPO specifically supports the following requirements.

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
1	TPG	Strategic Offense	Critical
2	TPG	Strategic Defense	Critical
3	TPG	Tactical Warfare	Critical
4	TPG	Reconnaisance/ Intelligence	Desirable
5	TPG	Airlift	Significant
6	TPG	Policy Goals	Significant
7	TPG	Technology Base	Critical
8	TN-ASD-72-535	Accumulation of Cost Data for improvement of cost estimating methods for advanced systems concepts	Desirable
9	TN-ASD-74-31	Threaded insert Evaluation	Significant
10	TN-ASD-74-32	Fastener and hole Gaging System	Significant
11	TN-ASD-74-33	Optimum Fastener Head and Recess	Significant
12	TN-ASD-77-22	Test Method for Less Expensive Mechanical Parts Qualification and Inspection	Significant
13	TN-SAMSO-AFML-1101-7036	Adhesive Bonding of Dissimilar Materials for Space Systems	Significant
14	TN-ASD-77-31	Low Cost Titanium Aircraft Structures	Significant
14a	TN-ASD-77-32	Life Cycle Cost Evaluation of Bonded Aluminum Honeycomb	Significant
15	TN-ASD-77-33	Corrosion Testing which Correlates with Field Experience	Significant

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
16	AFSC Development Goal SO-2	Penetrate Soviet Defenses	Significant
17	AFSC Development Goal SO-3	Destroy Objective Targets	Significant
18	AFSC Development Goal SO-4	Reconstitute the Strategic Attack Force	Significant
19	AFSC Development Goal SD-5	Provide the Information to Respond to a Bomber/Bomber Launched Missile Attack	Significant
20	AFSC Development Goal SD-6	Provide an Atmospheric Interdiction Capability	Significant
21	AFSC Development Goal TW-1	Provide Surveillance of Airborne Targets	Significant
22	AFSC Development Goal TW-2	Eliminate Airborne Threat	Significant
23	AFSC Development Goal TW-4	Neutralize Fixed Surface Targets	Significant
24	AFSC Development Goal TW-6	Neutralize Mobile Surface Targets	Significant
25	AFSC Development Goal RI-1	Collection of Data and Information	Significant
26	AFSC Development Goal AL-1	To Airlift Unit Equipment and Personnel to Areas where the US becomes engaged in a conflict - Requirements for Europe are the most stringent	Significant
27	AFSC Development Goal AL-2	To provide Intra-Theater Significant Transportation for Goods and Personnel which is not provided by Surface Transportation	Significant

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
IMPROVED STRUCTURAL INTEGRITY	78011F		400	350	250			
Initial Quality Holes			1 1	2	1-7, 17-28			
IMPROVED STRUCTURAL INTEGRITY	62102F	1132	985	1145	997	1270	1130	1300
Materials Properties and Control	2418	13	13 1	13 2	13	13	13	14 1-7, 15, 17-27
	62205F	(23)						
	NAVY	(55)						
	NASA	(25)						
	FAA	(35)						

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
ACQUISITION COST REDUCTION	62102F	14	0/100	50/170	200/100	200/150	230/100	300/250
Aluminum Adhesive Bonded Structure	2418		△1		1	1	1	1
	78011F	376 1	1000 1 △2	750 1 △3	500 1	800 1	1000 1 ▽ 1-7, 15, 17-27	
ACQUISITION COST REDUCTION	78011F							
Applications of AF 1410 For Cost Reduction		75 1 △1 ▽ 1-7, 17-28						

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
ACQUISITION COST REDUCTION Aluminum Castings	78011F	950 2	200 1 1	500 2 1-7, 17-27				
ACQUISITION COST REDUCTION Built Up Low Cost Advanced Titanium Structure	62102F 2418 64212F	15 1 (200)	100 1	85 1				
	78011F	1778 3	1000 3 1,3,5, &7	1800 3 2&6	1800 3 4&8	3550 3	2500 3	1500 3 1-7, 14, 17-27

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
ACQUISITION COST REDUCTION Thick Section Titanium	78011F	409 2 2	1900 2 1,3,4	1250 2	1100 2	1000 2	1500 2	2000 2 1-7, 14, 17-27
ACQUISITION COST REDUCTION Metal Removal	78011F		1 3	1500 2 2	1950 2	1600 2	2000 2	2500 2 1-7, 17-27

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
COST OF OWNERSHIP REDUCTION Corrosion Control	62102F 2418	55 1 △1	114/100 1 △2&3	150 1	70/100 1			
	78011F	172	200	200	200 ▽ 1-7, 16, 17-27			
COST OF OWNERSHIP REDUCTION Mechanical Fasteners	62102F 2418		0/100 △1	50/100 △3	150	150	150/100 1	200/100 1 ▽ 1-7, 9-11, 17-27
	78011F	405 1	350 1 △2	600 1 △4	900 1	250 1		

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
COST OF OWNERSHIP REDUCTION	62102F							
Metallic Structure Repair	2418	63 1 △1	30/100 1 △3	20/100 2	145/200 2	235/200 2	300/100 2	300/100 2 ▽ 1-7, 17-27
	78011F		350 △2	350				
COST OF OWNERSHIP REDUCTION	78011F							
Reduced Life Cycle Cost Landing Gear		85 1 △1	300 1 △2 ▽ 1-7, 17-28					

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
EXPANDED PERFORMANCE	62102F							
Crack Growth Resistant Powder Aluminum Alloy	2418	20 1	100 1	100 1 △1				
	78011F	350 1	800 1	400 1	1300 2	800 2	1000 2 1-7, 17-27	
METALS AND ALLOYS	61101F ILIR	100						
	62711E	(364)						
	62102F 2418	562 7	550 7	806 7 △1 △2	848 7 △3	900 9	900 9	900/200 9 1-7, 17-27
	OC-ALC	(3)						

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE	PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
METALLIC MATERIALS BEHAVIOR	62102F	2418	586 11	563 11	500/100 11	660/100 11	475/100 12	480/100 12	500 12 1-7, 17-27
	61101F	ILIR		100					
	78026F		(335)						
	64757F		(29)						
JOINING AND PROCESSING	61101F	ILIR			100				
Analytical Process Modeling	62102F	2418	79 2	80/100 2	64 2 1	40 2 2&3 1-7, 8, 17-27			

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE	PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
JOINING AND PROCESSING	62102F								
		2418	577 3	500 3	536 3	560 3	325/100 5	195/250 5	500 5
Enhanced Materials Utilization and Conservation	61101E		(1280) 1	1&2 (1145) 1	(950) 1	(480) 1			1-7, 17-27
ADHESIVE BONDING	61101F								
		ILIR				100			
	62102F								
		2419	710 5	375/250 5	740/100 5	585/150 5	560/150 5	470/150 5	600/350 5
									1-7, 13, 17-27

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
ADVANCED COMPOSITE MATERIALS DEVELOPMENT	62102F 2419	265 1	610 1	700 1	1010 1	950/100 2	600/200 2	350/400 2 1-7, 17-27
	78011F	497 1	1000 1	800 1	500 1			
ADVANCED FABRICATION	78011F	1750 2	2400 2 2	2950 2 1	2450 2 3	2000 2	1000 2	1000 2 1-7, 17-27

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PRODUCTION CONFIDENCE	78011F	1923	1200	1050	3550	4500	5000	3000
		2	2	2	2	2	3	3
								1-7, 17-27
ADVANCED COMPOSITE MATERIALS DURABILITY	62102F 2419	380	1330	600/100	542/300	375/200	275/300	
		1	1	1	1	1		
			2	1	3		1-7, 17-27	
	78011F	200	1200	1300				
		1	1	1				

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
NONMETALLIC COMPOSITES	62102F		755	1080/250	1205	1233	1600	1520	1600
		2419	11	11	11	11	11	11	11
					1	2			1-7, 17-27
POLYMERS FOR STRUCTURAL MATERIALS	62102F		700	800/250	950	950	1015/200	1537	1600
		2419	10	10	10	10	10	10	12
					1	2			1-7,13, 17-27
	61101F						100		100
		ILIR							

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
NDE OF FASTENED JOINTS	62102F	287	181	155	160	165	165	300
	2418	1	1	1	1	1	1	1
		1	2	3				1-7, 9-12, 17-27
	78011F	150	350	500	300			
		1	1	1	1			
FIELD NDE RELIABILITY IMPROVEMENT	62102F	85	75/250	400	200			
	2418	1	1	1	1			
				1	2			
	78011F	745	455	500	500	800	800	1000
		1	1	1	2	3	3	3
								1-7, 9-12, 17-27

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
COMPOSITES IN SERVICE INSPECTION METHODS	62102F	2418	8 2	72					
	78011F		60 1	200 1	500 1	300 1	800 1	1200 2	2000 2
				1	2	3			1-7, 9, 17-27
ADHESIVE BOND EVALUATION	62102F	2418	85 2	104 1-7,9-12, 13, 17-27					
	64708F		(11)						

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
NDE OF COMPLEX SHAPES	62102F							
	2418	125 2	6					
	78011F	435 1	1195 1	500 1	900 1	400 1		
			1,2,3				1-7, 17-28	
ENERGY STRUCTURES INTERACTIONS	62102F							
	2418	357 4	925 4	819 4	850 4	1800 4	1800 4	1000 4
								1-7,17-27
	NAVY	(22)						
	ARMY	(26)						
	61101F ILIR						100	

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
COMPUTER AIDED MANUFACTURING	64225F	(18)						
	78011F	2000	11100	13700	15700	16000	16500	16500
		2	13	15	15	15	15	15
								1-7, 8, 17-27

AFML TPO-2 AEROSPACE STRUCTURAL MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
TOTALS:								
FUNDS								
61101F		100	100	100	100	100	100	100
62102F								
2418		4050	4385/750	4845/470	4880/500	5520/550	5350/550	5300/650
2419		2810	4195/750	4195/200	4320/450	4500/650	4400/650	4150/750
78011F		12360	25600	29500	32200	32500	32500	29500
PE 62102F 06DS		6325	6350	6475	6625	7085	7590	8150
PE 63211F Reimbursement			(198)	(213)	(230)			
Non-Add								
62205F		(23)						
64212F		(200)						
64225F		(18)						
78026F		(335)						
64757F		(29)						
64708F		(11)						
61101E		(1280)	(1145)	(950)	(480)			
62711E		(364)						
OC-ALC		(3)						
NAVY		(22)						
ARMY		(26)						
NASA		(25)						
ARMY		(55)						
FAA		(35)						
TOTAL TPO FUNDING		28046	41973/ 1500	46278/ 670	48835/ 950	49705/ 1200	49940/ 1200	47200/ 1400
MANPOWER								
S, E & T Direct MY		105	109	111	111	111	111	111

TECHNOLOGY PLANNING OBJECTIVE

TPO NUMBER 3 TITLE AEROSPACE PROPULSION MATERIALS

GENERAL OBJECTIVE AND INVESTMENT STRATEGY:

Provide improved material and/or processes for application to current and future aircraft and rocket motor propulsion systems. Emphasis is in the areas of disks, turbine blades and vanes, fan and compressor blading, coatings, gas path seals, materials processing and joining, nondestructive inspection methods, and solid rocket nozzles. This dictates interest in titanium alloys, metallic as well as nonmetallic matrix composites, superalloys, dispersion strengthened alloys, directionally solidified alloys and eutectics, titanium aluminides, ceramics, and carbon/carbon composites.

The investment strategy in this TPO is driven by considerations of reducing the high acquisition and ownership cost, increasing durability, and providing increased performance. The TPO will experience and overall increase in resources in the FY79-FY83 time frame to meet these systems and operational needs. Some specific areas where the TPO has a major impact include development goals concerned with capabilities in strategic offense for launch of the strategic attack force, penetration of Soviet defenses, the ability to destroy objective targets, and the capability to reconstitute the strategic attack forces; capabilities in strategic defense for providing a space defense system for the US and the ability to provide an atmospheric threat interdiction; capabilities in tactical warfare to provide surveillance of airborne targets to eliminate an airborne threat, to neutralize fixed surface targets, to neutralize mobile surface targets, capabilities in reconnaisance for collection of data and information; and capabilities in airlift to airlift unit equipment to areas where the US becomes engaged in a conflict and to provide intra-theater transportation for goods and personnel which is not provided by surface transportation. In addition the TPO impacts policy goals on life cycle costs and energy. The overall program to meet the needs involves emphasis in the areas of low acquisition cost materials, life cycle management, improved performance and technology base developments. In the next five year period, emphasis will increase in the acquisition cost area and in selected aspects of the performance and technology base programs. The work on life cycle management will also increase at a moderate rate to reduce operation and maintenance costs.

SPECIFIC GOALS AND TECHNICAL APPROACHES:

Within this TPO there are nine major thrusts. Work on Low Acquisition Cost-Metals is concerned with efforts on titanium cases and frames, metal removal, titanium disks, turbine airfoils, static parts and superalloy frames, fan compressor blad-

ing, and superalloy disks. In Low Acquisition Cost-Nonmetals there are developments in low cost fan blades and low cost engine static structure. Life Cycle Management is designed to address weld repair for superalloys, surface treatment and refurbishment, engine life prediction, and rejuvenation of engine components. Developments in Performance-Metals will emphasize materials for advanced turbine disks, titanium rotating components, hot section cores combustors and vanes, aluminides for static components, non combustible engine alloys, and engine seal systems for high pressure compressors and turbine work in Performance-Nonmetals/Composites will include eutectics, advanced composite rotating components and foreign object damage. The thrust on Rocket Propulsion is centered on nozzle materials while that on Small Engines stresses ceramic turbine components and turbine metal rotating components. The technology base portion of this TPO includes the thrusts of Ceramics and High Temperature Alloys.

Low Acquisition Cost-Metals

The efforts under this thrust deal with materials and manufacturing technology developments which will provide a reduction in costs on the order of 20-40% with no attendant degradation of life, performance, or reliability. The thrust will also provide alternate sources for metallic materials manufacturing and the industrial base for production. The results of these development activities will be to reduce life cycle costs in turbine engines, and to provide low cost, lightweight, high performance engine materials for advanced systems such as airlift, fighter and bomber aircraft and RPV's.

Titanium Disks - The goal of this program is to provide a 30% reduction in compressor disk production costs, and to improve low cycle fatigue properties. The overall approach involves use of titanium powder technology and powder metallurgy process development to produce new net shape parts. One of the pacing problems which will be addressed in this thrust is the manufacture of suitable titanium powder with controlled properties and purity. Investigations will include the currently used rotating electrode process and other processes such as melt extraction. Process developments will include work on hot isostatic pressing and vacuum hot pressing of parts. Computer controlled processes will be included in the program. Key decision points involve (1) a resolution of high quality titanium powder availability, and (2) whether a nondestructive evaluation capability is available for hot pressed near net shapes.

Turbine Airfoils - The objective of this direction is to provide both a 40% cost reduction and an alternate manufacturing process for directionally solidified superalloy Turbine Airfoils. Specific programs address automation of the directional solidification process, and scaleup of advanced coating processes. Specific milestones include (1) qualification of alternate coating processes, (2) need for scaleup of a direc-

tional solidification process, (3) the need for coating process scaleup, and (4) a decision on whether availability of an acceptable powder source has been demonstrated.

Static Parts Superalloy Frames - The goal of this program is to provide a minimum savings of 20% for fabricated turbine components through improved manufacturing technology developments and to achieve a 50% increase in service life of hot section components through advanced casting processes, improved materials, and welding improvements. Specific programs address casting of integral rotors, pulsed current plasma arc welding, and development of compatible filler wire.

Metal Removal - The goal of this program is to optimize near net shape techniques, to improve high speed machining and to develop innovative machining for improved productivity and capacity. Efforts include near net shape economic modeling, design and machining data, advanced metal removal techniques, profile milling mathematical modeling, innovative tools and methods evaluation, and high speed machining for engine components.

Titanium Cases and Frames - The objective of this direction is to achieve a 30% cost reduction for lightweight hybrid frames based on developments in titanium casting technology sandwich panel fabrication, titanium alloy weldability and braze assembly scale up. In the casting technology area, emphasis will be placed on high integrity casting and definition of quality standards. Other areas of development will include bonded titanium compressor cases, and sandwich panel fabrications leading to F100 uses, and advanced frame and case fabrication needs. The major milestones in direction involve (1) a decision to initiate full scale production of a test article aft fan duct, and (2) a selection of technologies which can be usefully employed in large inner and/or outer engine cases.

Fan and Compressor Blading - This work has the goal of reducing manufacturing lead time which will result in a 20% cost reduction of these components. The primary program in this direction is concerned with isothermal forging of titanium blades. Other major efforts will include computer aided design and manufacturing efforts on forging of titanium blades.

Superalloy Disks - This direction has the objective of a 40% cost reduction for superalloy based turbine disks with improved reliability. The basic program centers on the manufacturing savings that can emanate from using powders and near net shape production techniques. Specific programs will investigate superalloy powder production, nondestructive inspection of near net disks, near term near net disks for F100 engines, near net shape disk production, and bore entry cooled disk production. One of the basic problems is the development of acceptable consolidation and post compaction processing capable

of attaining properties equivalent to wrought disks. Other factors involve considerations of tolerance control and adequacy of nondestructive evaluation (NDE) techniques. The NDE capability is the first major milestone in the area with the second being whether powder metallurgy is suitable for bore entry cooled disks.

Low Acquisition Cost-Nonmetals

This thrust involves primarily advanced development efforts in composites and manufacturing technology improvements designed to eliminate use of strategic materials and reduce costs of fan blades and engine static structures made from reinforced organic resin based composite materials. In addition, a 30% reduction in component weight is expected. This thrust will reduce life cycle costs in turbine engines as well as provide weight reduction which will lead to energy savings and increased performance in advanced turbine engines for fighter, bomber and airlift aircraft.

Low Cost Fan Blades - The goal of this direction is to achieve a 30% cost and weight savings over conventional F 103 blades. It also has the goal of achieving foreign object damage resistance for composite fan blades. Specific efforts include flight testing of composite F 103 blades, and low cost manufacturing process development. Several of the above programs will extend work which has already demonstrated automated pickup of plies in a continous manner, automated inspection of large blades and automated pressing of composite blades. Work will explore computer layout for maximum materials use, automatic pickup and assembly of plies, high temperature materials and NDI techniques for determining flaws. The major milestone which is critical to this program is a decision to start advanced assembly development programs predicated on the successful demonstration of composite fan blades in the earlier F 103 fan blade effort.

Low Cost Engine Static Structures - This program has as its objective the advanced development of materials and manufacturing processes which will provide a 30% cost savings over current metal components. Specific programs involve composites for static structures such as ducts and frames using current composite technology. Advanced structures developments for frames will be undertaken using graphite epoxy or graphite polyimide materials. Work will also be conducted on the development of repair techniques for ducts and low temperature frame manufacturing.

Life Cycle Management

Increasing costs for labor and replacement parts have made maintenance costs for USAF engines a prime driver in the overall cost of ownership arena. The thrust on life cycle management

is designed to increase service life of turbine engine components 30-50%, to reduce incidence of failures in engine components in turbine engines. This is done through engine life prediction developments, rejuvenation of engine components, surface treatment and refurbishment, weld repair techniques for superalloys, and addressing factors such as titanium combustion, damping and component integrity. These activites impact in a major way goals of life cycle cost savings and our ability to provide turbine engine operation over longer periods of time with assured performance in situations such as where it is necessary to reconstitute the bomber attacking forces and operate airlift forces for extended period of time.

Weld Repair for Superalloys - The goal of this direction is to provide a weld repair capability for superalloys which can be used by Air Logistic Centers and which will result in a 30% cost avoidance improvement and a 10% improvement in production yield. Repair areas which are impacted by this program result from tip wear, leading edge erosion and thermal fatigue and hot corrosion. Specific programs include compatible filler alloys for superalloys, process development and scaleup for blade weld repair, repair of knife edge seals, and repair for drum rotors. Milestones involve consideration of timeliness of process scaleup.

Surface Treatment and Refurbishment - This direction is concerned with providing AFLC with a capability to do recoating of engine components at the Air Logistic Centers during engine overhaul periods. The primary problem in this area is that the turbine airfoil coatings have to be replaced during overhaul, and there are many proprietary versions. The approach is to develop a single nonproprietary coating process for the aluminides, applicable to the variety of Air Force alloys and parts. Specific programs include definition of the aluminide coating process for in-service alloys using an electrophoretic deposition process, and production coating process scaleup. A second is to develop an automated process for applying sprayed coating. The first milestone is to establish equivalence of the recoating process to original equipment coatings, and to verify for production. The second is to demonstrate recoating of AFLC engine parts and determine feasibility of AFLC facility use.

Titanium Combustion - This direction has the goal of understanding and then limiting the catastrophic effects of titanium ignition and propagation. Work will include efforts on development of techniques (probably involving coatings) to prevent or retard the combustion process. The major milestone involves a decision on the availability of a satisfactory protective technique and the need for process scaleup.

Engine Life Prediction - This direction has as its goal programs to develop life prediction techniques which optimize useful life of engine components and to develop high temperature fracture mechanics necessary to apply damage tolerant criteria to engines. This is done under the three basic areas of initiation, crack propagation, and design criteria. Specific

programs designed to understand the initiation process include development of predictive capability under combined creep and fatigue conditions including a study of their interactions and work on mechanical testing and evaluation, including elevated temperature testing. All of this leads to an evaluation of advanced prediction models. In the area of crack propagation, there are efforts on crack growth at elevated temperature, application of failure mechanics to turbine disk materials, microcrack growth, crack propagation under thermal mechanical cycling, and engine demonstration and validation work. The design criteria studies include work on residual disk life, retirement for cause, experimental evaluation of advanced models, and preparation of engine damage tolerant specifications. Milestones include (1) a critical assessment of advanced prediction models for real engine environments as an input to the evaluation work, and(2) an assessment of fracture mechanics technology. The total thrust is integrally related and continuously coordinated with ASD and AFAPL efforts in the related hardware aspects.

Rejuvenation of Engine Components - This direction has the objective of restoring original mechanical properties to used engine components which have degraded in service. It also strives to obtain increased design allowables on engine components such as a 30% increase in low cycle fatigue. Specific efforts include hot isostatic pressing studies for rejuvenation of fatigue and creep damage, thermal rejuvenation of Ti blade alloys, and fan disk life extension work. Specific milestones include (1) demonstration of a capability to heal fatigue damage, (2) engine testing, and (3) assessment of thermal rejuvenation.

Vibration Damping - The goal of this direction is to transition high temperature damping technology to Air Force uses and the aircraft engine industry. Specific efforts involve low cost elastomeric processing. materials measurement support, rotating structure, high cycle fatigue, creep and rupture studies, and engine damping materials manufacturing and processing.

Component Integrity - The goal of this direction is to increase component integrity through improved manufacturing processes. Specific efforts address metal matrix shaft fabrication, roller bearing metrology, laser heat treatment of bearing races, and development and scale up of fracture tough bearings.

Performance Metals

This thrust is concerned with materials development and manufacturing technology advancement which will lead to advanced metallic materials for fan, compressor, turbine, combustor and other components having improved high temperature capability, reliability, strength to weight, oxidation and erosion resistance to improve engine efficiency including

thrust to weight and reduced specific fuel consumption. These developments are significant factors in designing advanced turbine engines which will be required for the performance improvements needed for the tactical systems needed to neutralize surface targets, the reconnaisance system needed for data collection, and the defense aircraft needed to provide atmospheric threat interaction capability.

Advanced Turbine Disks - This direction has the goal of developing, applying, and validating alloys and fabrication processes for disks capable of 1400°F use. The major approach is to use new powder metallurgy alloys to allow the manufacture of a bore entry cooled disk. The powder metallurgy work involves development and manufacturing scaleup of alloys which will allow greater performance and durability as well as optimization to near net shape production. NDE techniques constitute a significant factor in this and other powder metallurgy programs. Key decision points involve (1) selection of the alloy for the powder metallurgy process, (2) verification of materials needs for bore-entry disk requirements, (3) establishing feasibility for powder metallurgy net shape fabrication, and (4) availability of required nondestructive evaluation capability.

Titanium Rotating Components - The goal of this direction is to improve processing, alloys, and specifications for titanium rotating component materials with a 20% greater low cycle fatigue life at 800°F. These materials are needed for growth and advanced engines for APU's, RPV's and various aircraft engines. Specific studies include work on a test to define hot salt stress corrosion behavior of titanium alloys for engines, producibility, and reliability of candidate high temperature titanium alloys, and development and processing of a high performance titanium disk. Major milestones include (1) whether the AFAPL is prepared to pursue a centrifugal compressor engine, (2) selection of the best alloy candidate for future elevated temperature use in disks, and (3) what the next generation compressor disk alloy specification will be.

Aluminides For Static Components - The objective of the work in this direction is to develop a manufacturing and fabrication capability for titanium aluminide intermetallics for light weight static parts operating to 1200°F. Specific efforts involve alloy development, alloy characterization, study of feasibility of manufacturing processes, work on joining, rolling and forging, design criteria of manufacturing process verification. Milestones involve (1) alloy selection and processing feasibility determination, (2) determine need of next generation alloys, and (3) feasibility of component manufacture and alloy selection.

Non Combustible Engine Alloys - The goal of this direction is to develop nonburning alloys for light weight blades to operate at temperature to 1600°F as possible substitutes for present titanium alloy blades. Specific developments will include titanium aluminide alloy characterization and development, titanium aluminide joining and rolling and manufacturing process verification.

Hot Section Core, Combustor and Vane (220°F)- This has the goal of providing (1) $Ni\text{-}Cr\text{-}Al\text{-}Y_2O_3$ vane materials operating up to 2000°F uncoated, (2) combustor materials operating at 2000°F uncoated, and (3) $Co\text{-}Ni\text{-}Cr\text{-}Al\text{-}Y_2O_3$ vane materials operating up to 2200°F uncoated. The work will extend previous efforts on oxide dispersion strengthened cobalt and NiCr materials to manufacturing process development and component manufacturing. Specific efforts will involve manufacturing development of advanced vanes, studies of high temperature sheet rolling, and manufacturing development of an advanced ODS combustor. The major milestone involves an assessment of whether the ODS cobalt alloy/process development is ready for transition to manufacturing of advanced vanes, or to continue primary effort on ODS Nickel alloys.

Engine Seal Systems For High Pressure Compressor and Turbine - The overall goal of this direction is to reduce specific fuel consumption through increased performance efficiencies. One program will address the mating of the shroud with the sealing surface on the blade tips to get improved durability and performance. Work on 1250°F engine gas seals involve engine demonstration of seal materials. An important factor in seal technology is plasma spray processing of wear resistant coatings and work will be devoted to automation studies to ensure process control.

Performance Nonmetals/Composites
This thrust is primarily concerned with the development of composite materials which will provide for increased thrust to weight performance in engines while not increasing costs engine components and providing fail safe designs. Major emphasis is in nonmetallic and metallic composites and metal eutectic technology. The efforts in this area involve major payoffs in goals of life cycle cost savings and engine performance needed for advanced fighter, bomber and airlift aircraft.

Eutectics - The goal of this direction is to provide alloy development and processing technology for a material which will have a stress rupture capability equal to 250°F above that of alloys used in current engines such as René 80. The work is based on the nickel tantalum carbide DS eutectic family. Specific programs will address coatings development, low pressure and high pressure blade development and demonstration, advanced casting and fabrication development, development of acceptance and reject criteria, and work on low cost manufacturing. Major milestones on the roadmap involve consideration of (1) when the high pressure blade development should be initiated, and (2) whether the alloy defined will meet the program needs.

Advanced Composite Rotating Components - This direction has the goal of developing technology for fan blades with a capability of high tip speed at 600°F. Additional objectives include foreign object damage resistance, 10% improvement thrust to weight capability, and 20% acquistion cost saving.

Specific programs include blade development, engine flight test, advanced rotor development, and development of repair processes. Specific milestones include (1) whether FOD capability is satisfactory, and (2) whether a follow on process for blade development is required.

Foreign Object Damage - The objective of this direction is to provide the design methodology and criteria for foreign object damage resistant fan blades considering both gross and local damage. Specific efforts include work on materials dynamic behavior, material rate effects. FOD loading methodology, and blade development and testing. Milestones include (1) whether specimen-blade correlations exist, (2) whether bird-blade interactions are adequately defined, and (3) whether design approaches are satisfactory to predict blade effects.

Rocket Propulsion

This thrust is primarily concerned with the goal of providing reliable high performance nozzles for full scale rocket engines and exit cones. The basis for the improved nozzles lies in the carbon/carbon composite material technology being developed in TPO-1 and elsewhere in the materials program. The program is also designed to replace the current cut and try process used in selection of flightweight materials for hardware. Initial work will be done on assessing carbon/carbon materials for fabrication into small 2"-4" nozzles for motor firings. After fabrication and testing of these materials, work will be done on nozzle scaleup to the 7-15" size with subsequent test firing. During the course of the program, companion efforts will be devoted to carbon/carbon densification, process improvements, thermostructural characterization, and failure criteria studies for carbon/carbon materials. Another phase of this program will attempt to improve the capability to predict recession (ablation) rates for carbon/carbon materials in the solid propellant exhaust environment, and to provide pre and post test predictions for selected nozzle tests. The payoff for this work is that the prediction capability will reduce the risk of initial design and provides a tool for analysis of performance variation with motor design. Specific milestones in the thrust include questions of (1) whether small scale rocket firings and other tests can identify carbon/carbon candidates for scaleup, (2) whether follow on carbon/carbon developments can be optimized for erosion resistance, and (3) what are the final materials to be selected for the advanced nozzle program. The technology development in this program will have critical impact on the propulsion system performance for MX and also will be significant to smaller rocket motor systems for advanced air to air, and air to surface tactical missles as well as spacecraft thrusters.

Small Engines

This thrust is concerned with propulsion materials and manu-

facturing technology for small turbine engines for missile remotely piloted vehicles, and auxiliary power units. The major area of materials covered is that of ceramics, with some work on titanium and superalloys. Significant payoffs derive to advance air launched strategic missiles and tactical missiles.

Ceramic Turbine Components - The goal of this direction is to demonstrate and validate ceramic materials for small engine uncooled turbine parts. This would lead to a 50% thrust increase over engines using present materials technology. Efforts will concentrate in the areas of microstructural and property screening and characterization of materials, and improved materials processing and fabrication. The materials selected in these programs will be assessed in component development and test programs being constructed by the AFAPL. Milestones in the program are primarily involved in selection of materials for the AFAPL program, and in assessing materials properties after component rig testing by AFAPL.

Turbine Metal Rotating Components - This direction has the major objective of verifying availability of low cost fabrication processes for turbine components. Efforts in this thrust include manufacturing technology programs on hybrid turbine airfoils and dual-property rotors. Another aspect is to determine whether squeeze casting can be scaled up. These studies will then guide advanced manufacturing technology programs.

Ceramics

This technology thrust is concerned with providing reliable and affordable ceramics for limited life engines and radomes/IR domes. Specific efforts include characterizing various ceramic materials, developing life prediction techniques, and providing processes which will allow truly low cost ceramic components to be made. The effort impacts goals concerned with missile propulsion and detection systems in a significant manner.

High Temperature Alloys

This technology thrust is concerned with new materials such as superalloys tailored for powder metallurgy fabrication, titanium aluminides, and coating materials. Specific goals of the thrust are to define titanium aluminides specifically designed for 1200°F static parts, to develop nonburning alloys, directionally solidified (DS) eutectics, and to develop advanced powder metallurgy disk alloys. Specific programs involve alloy characterization, fabrication parameters, coatings developments, fatigue property determination and processing variables. These materials play a significant role in the advancement of turbine performance for future aircraft systems.

RELATED EFFORTS:

AFML is closely following AFAPL and AFRPL programs, those of the Navy and Army, the Engine CIP activities, and all IRAD efforts. To cite all such efforts and associated impact on AFML programs would be too voluminous. Several of particular interest are worthy of mention, as for example, G.E.'s project on boron/aluminum fan composites, TRW's project on advanced metal composites, P&W's project on spar and shell blade development, the Navy's development and test program on beryllium/titanium composite blading, NASA's development and evaluation effort designed to provide boron/aluminum composites with superior resistance, AFAPL'S APSI-ATEGG program which provides for demonstration of much of AFML's new "products," AFRPL's component development efforts in support of the MX-ADP in which AFML has a principal role in the advanced nozzle throat inserts, NASA's efforts on seals, the lack of Army and Navy attention to nonferrous metal joining, and the Army's ceramic turbine efforts with Westinghouse and Ford sponsored by ARPA. Other efforts on ceramic materials are being followed closely through an interagency coordination group; for example, the NASA-Lewis Laboratories have programs with different approaches to develop Si_3N_4 and SiC for turbine vanes; programs supporting the general area address the development of improved fracture energy of these materials. The Naval Air Systems Command has a number of programs which include the development of Si_3N_4 refactory metal composites for turbines, metal-ceramic materials for seals, ceramic-metal thermal barriers for turbines and ceramics for rolling element bearings. Industry efforts on ceramics pertaining to this TPO include work on ceramics for combustors (Allison Div) turbine blades (TRW, Teledyne) and bearings and seals (Allison Div.)

REQUIREMENTS:

Efforts under this TPO impact most propulsion systems for most AF systems and options. Summarizing the more critical options with which this TPO will or is now interfacing:

Strategic Offense - materials for high performance, lightweight propulsion system for ICBM's; Strategic Defense - materials for turbojets and composite ramjets for high Mach number with long range cruise capabilities as well as materials for solid propellant rocket motors and integral rocket/ramjet combustors for air-to-air missiles; Tactical Warfare - materials for transonic and supersonic engines for Air Interdiction such as the ATF, for STOL systems, VTOL systems, strike fighters for close air support and direct lift engines and lift cruise fans. Needs/opportunities are also apparent in Tactical Warfare for materials and processes for cheap, short-life engines for RPV's. Special Operations - earlier indicated STOL and other CAS type materials needs are applicable

hereto; Air Lift - Special materials needs associated with long-range engines exist, as do needs for STOL systems e.g.AMST; Reconnaissance and Surveillance - highly survivable, repetitive use, unmanned systems, e.g. Low Altitude Tactical Reconnaissance Systems, essentially a high performance RPV, introduces materials requirements quite different from cheaper, more limited use RPV systems that will probably be involved in the Fighter Attack areas; Mission Support - the full Scale Maneuvering Target and the Bomber Defense Target, depending on configuration and performance details, could introduce materials needs which might render the applicability of this TPO either "critical" or "significant;" and Technology Base - materials efforts under this TPO, not currently being pursued, would be "critical" to the achievement of either high mach number or hypersonic systems. This program also supports the F100, TF30-P100, J33, J75,TF34, and other engines in providing low cost materials and manufacturing methods to reduce the acquisition and O&M of the engines. The TF41 and TF30-P100 engine O&M costs are supported in this area through work on lower cost and more durable turbine vane and blade materials which will decrease the frequency of overhaul and reduce blade replacement costs.

Requirement Identification Number	Requirement Number	Requirement Title	Applicability
1	TPG	Strategic Offense	Critical
2	TPG	Strategic Defense	Critical
3	TPG	Tactical Warfare	Critical
4	TPG	Airlift	Critical
5	TPG	Reconnaisance & Intelligence	Critical
6	TPG	Policy Goals	Significant
7	TPG	Tech Development	Critical
8	TN-ASD-74-34	Damping Treatments for Jet Engine Components	Significant
9	TN-SAMSO-76-03	Carbon Materials for Rocket Nozzle Application	Significant
10	TN-SAMSO-76-41	Post Boost Propulsion	Desirable
11	TN-SAMSO-AFML-1106-71-73	Nondestructive Testing and Property Correlation in Graphitic materials	Significant
12	AFSC Development Goal SO-1	Launch the Strategic Attack Force	Desirable
13	AFSC Development Goal SO-2	Penetrate Soviet Defenses	Significant
14	AFSC Development Goal SO-3	Destroy Objective Targets	Desirable
15	AFSC Development Goal SO-4	Reconstitute the Strategic Attack Force	Desirable
16	AFSC Development SD-4	Provide a Space Defense System for US.	Desirable

Requirement Identification Number	Requirement Number	Requirement Title	Applicability
17	AFSC Development Goal SD-6	Provide an Atmospheric Threat Interdiction Capability	Significant
18	AFSC Development Goal TW-4	Neutralize Fixed Surface Targets	Significant
19	AFSC Development Goal TW-6	Neutralize Mobile Surface Targets	Desirable
20	AFSC Development Goal TW-1	Provide Surveillance Airborne Targets	Desirable
21	AFSC Development Goal TW-2	Eliminate Airborne Threat	Desirable
22	AFSC Development Goal RI-1	Collection of Data and Information	Desirable
23	AFSC Development Goal AL-1	To airlift unit equipment and personnel to areas where the US becomes engaged in a conflict-requirements for Europe are the most stringent.	Desirable
24	AFSC Development Goal AL-2	To provide intra-theater transporation for goods and personnel which is not provided by surface transportation	Desirable
25	AFSC Policy Goal 1	Life Cycle Cost	Significant
26	AFSC Policy Goal	Energy	Significant

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LOW ACQUISITION COST METALS Titanium Disks	78011F	711 1 1	600 1		500 1 2	400 1 1-7, 12-15, 17-27		
LOW ACQUISITION COST METALS Turbine Airfoils	62102F 2420	105	35					
	78011F	392 1	688 1 1 2	677 2 3	300 1 4	300 1	600 1	600 1 1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LOW ACQUISITION COST METALS Static Parts/ Superalloy Frames	78011F	605 1	720 1	200 1 1-7, 12-15, 17-27				
LOW ACQUISITION COST METALS Titanium Cases/ Frames	78011F	654	350 1		400 1 2	500 1	600 1	600 1 1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LOW ACQUISITION COST METALS Metal Removal	78011F			700	600	1000		
				1				
						1-7, 12-15, 17-27		
LOW ACQUISITION COST METALS Fan/Compressor Blading	78011F	273	306		450	600	300	300
		1	1			1	1	1
								1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LOW ACQUISITION COST METALS	78011F	400	500	250	250			
Superalloy Disks			1	2	1-7, 12-15, 17-27			
LOW ACQUISITION COST NONMETALS	78011F	480	300		500	1000	1600	1600
Low Cost Engine Static Structures		1	1		1	1	2	2 1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LOW ACQUISITION COST NONMETALS	78011F	200			300	600	300	300
Low Cost Fan Blades				1				1-7, 12-15, 17-27
LIFE CYCLE MANAGEMENT	62102F 2420				50	100	0/100	
Vibration Damping	78011F			400	450	200	600	600
				1	1	1	1	1
								1-8, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LIFE CYCLE MANAGEMENT	62102F							
Titanium Combustion	2420		50/100	140	50			
	78011F			300	300	300		
						1-7, 12-15, 17-27		
LIFE CYCLE MANAGEMENT	78011F	725	500	600	300			
Weld Repair For Superalloys		1	1	1	1			
					1-7, 12-15, 17-27			

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LIFE CYCLE MANAGEMENT	62102F	109	485	480	550	495	450	600
Engine Life Prediction	2420	3	3	3	3	3	3	4
				1		2		1-7, 12-15, 17-27
LIFE CYCLE MANAGEMENT	62102F	135	12/100	50/100	100	100	250	200/100
Surface Treatment and Refurbishment	2420	1						
			1		2			
	78011F		650	400	300	250	900	900
			1	1	1	1	1	1
								1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LIFE CYCLE MANAGEMENT Component Integrity	78011F		200	200	400	200 1-7, 12-15, 17-27		
LIFE CYCLE MANAGEMENT Rejuvenation of Engine Components	62102F 2420	179	146	90	0/100			
	78011F	260 1	616 1 2	600 1 1	500 1 3	400 1	800 1	800 1 1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PERFORMANCE METALS Advanced Turbine Disks	78011F	150	300	750	400	600	800	800
			1&2	3	4			1-7, 12-15, 17-27
PERFORMANCE METALS Titanium Rotating Components	78011F	100	250		300	200		
			1 2		3	1-7, 12-15, 17-27		

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PERFORMANCE METALS Aluminides for Static Components	62102F 2420	181	45/100					
	78011F	100	200	300	250	250	300	300
			1	2	3			1-7, 12-15, 17-27
PERFORMANCE METALS Non Combustible Engine Alloys	62102F 2420	70	70	50	50	0/100	0/100	
	78011F			244	200	300	600	600
								1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PERFORMANCE METALS	62102F							
Hot Section Core Combustor and Vane	2420			50	50	0/100		
		350	300	600	300	300		
		1				1-7, 12-15, 17-27		
PERFORMANCE METALS	62102F							
Engine Seal Systems High Pressure Compressor and Turbine	2420	55						
	78011F	250	320	600	500	900	1500	500
		1	1	1	1	1	1	1
								1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PERFORMANCE NONMETALS	62102F 2420	244 1	30/100	50	100	150	200/100	300
Eutectics	78011F		2 600 1 1	700 1	450 1	300 1	1000 1	1000 1 1-7, 12-15, 17-27
PERFORMANCE NONMETALS	62102F 2420		130/100	450 1	295 1	490 1	330 1	200/100 1 1-7, 12-15, 17-27
Advanced Composite Rotating Components	78011F	100 1 1	600 1 2	700	450			

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PERFORMANCE NONMETALS	62102F	25	309	50	100	65/100	150	150/100
Foreign Object Damage			1 2	3				1-7, 12-15, 17-27
ROCKET PROPULSION NOZZLES	63411F	(25)						
	62302F	(24)						
	11213F	(55)						
	62102F	509	325	200	230	300	280	0/100
		1	1	1	1	1	1	
		1	2	3			1,2,7,9, 10,12,13, 14,15,16	
	78011F	690	560	1079	1000	1000		

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
SMALL ENGINES Ceramic Turbine Components	62203F	(40)						
	62102F 2420	100	63/100	100/100	100/100	100/100	100/100	300
	78011F	300	500	500	400		800	300
								1-7, 12-15, 18-21
SMALL ENGINES Turbine Metal Rotating Components	78011F	350	300		200	400	800	800
								1-7, 12-15, 18-21

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
CERAMICS	61101E		(95)						
	61101F	ILIR	100	100		100			100
	62102F	2420	15	15	15	15/50	15/50	115/50	150
			2	2	2	2	2	2	2
									1-7, 12-15, 17-27
HIGH TEMPERATURE ALLOYS	61101F	ILIR			100		100	100	
	62102F	2420	48	35	135	160/100	285	275	300/100
			2	3	3	3	3	3	3
									1-7, 12-15, 17-27

AFML TPO-3 AEROSPACE PROPULSION MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
TOTALS:								
FUNDS								
61101F		100	100	100	100	100	100	100
62102F		1775	1750/600	1860/200	1850/350	2100/450	2350/450	2500/500
78011F		7090	9360	9800	10000	10000	11500	10000
PE 62102F 06DS		1100	1190	1175	1190	1280	1360	1450
Non-Add								
62203F		(40)						
62302F		(24)						
11213F		(55)						
61101E		(95)						
63411F		(25)						
TOTAL TPO FUNDING		10304	12400/600	12935/200	13140/350	13480/450	15310/450	14050/500
MANPOWER								
S, E & T Direct MY		19	20	20	20	20	20	20

TECHNOLOGY PLANNING OBJECTIVE

TPO NUMBER 4 TITLE FLUIDS, LUBRICANT AND ELASTOMERIC MATERIALS

GENERAL OBJECTIVE AND INVESTMENT STRATEGY:

Provide materials and supporting technology for lubricants, energy transfer fluids, fluid containment and sealing. In the area of lubrication, materials are developed for liquid, semisolid, and solid lubricants for aircraft and spacecraft, along with an understanding and prediction of their performance. In the area of fluids, work primarily involves materials for hydraulic fluids and related heat transfer applications. In fluid containment and sealing, efforts are designed to provide fuel tank sealants, fluid system seals, expulsion bladders, and tires. The various areas encompass the complete scope of activity from the chemistry of synthetic modification to the engineering aspects involved in application to eventual system use. Investment in this TPO is driven by the extensive needs across the spectrum of Air Force requirements in strategic offense, tactical warfare, strategic defense, mission support, and command, control and communications. The lubricants, fluids and elastomeric material are all high cost operational and support items. From a performance point of view they play significant roles in strategic offense systems for penetrating Soviet defenses and destroying objective targets where high temperature performance defines operation of air launched missiles and gyro lubrication defines performance of missile guidance and control, in strategic defense systems where space lubricant performance defines satellite reliability in providing missile attack information and high temperature performance defines the performance capability of a FOI in the atmospheric threat interdiction role, in tactical warfare where the survivability and operation of an ATF type vehicle in acquiring surface targets is defined by high temperature capabilities, and in airlift roles where advanced sealants will reduce maintenance requirements. The role of the materials under this TPO are also significant in life cycle cost and energy policy goal requirements.

SPECIFIC GOALS AND TECHNICAL APPROACHES:

Within this TPO there are nine thrusts. Hydraulic Fluids involve efforts on high temperature, nonflammable hydraulic fluids. Programs in Fluid System Seals are concerned with seal systems for use with the nonflammable fluids. In the thrust on Integral Fuel Tank Sealants, emphasis is placed on O&M cost reduction, life prediction, and exploratory development. Instrument Lubrication addresses requirements for lubrication of miniature ball bearings and gas bearings. The thrust on Aircraft Tires is directed at the development of high temperature low O&M cost

tires. Polymers for Elastomer Materials covers the technology of polymers for seal materials and transparent materials. The objective of Accelerated Life Prediction is to predict lubricant behavior for space bearings. The thrust on Fluid and Lubricant Technology is concerned with the development of base fluids with 600°F stability. The thrust on Lubrication Systems Analysis explores oil analysis techniques and engine wear diagnostics.

Hydraulic Fluids

The major goal of this thrust is to develop a nonflammable hydraulic fluid for use in future aerospace systems in the temperature range -65 to 275°F. The approaches include fluid synthesis, formulation and characterization, flammability studies, and hydraulic pump testing. Major milestones involve: (1) a decision concerning continuation of work on chlorofluro-carbon and fluoro alkyl ether fluids for 275° base fluids, and (2) determination of the feasibility of reducing the cost of perfluoroalkylether and triazine fluids. This thrust has major impact on the life cycle cost policy goal and airlift systems development goals due to greater safety and reduced potential for system loss due to fire. It also impacts future advanced fighter aircraft where the current fluid will be unacceptable.

Fluid System Seals

The objective of this thrust is to develop seals for new nonflammable fluids over a series of temperature and pressure profiles including:

-65°F to 275°F/4000 psi

-65°F to 450°F/5000 psi

-65°F to 600°F/8000 psi

The effort includes back-up ring development, seal design and evaluation, elastomer synthesis and compounding studies. Specific milestones involve: (1) selection of classes of elastomers and back-up ring materials, and (2) determination of the feasibility of elastomers/seals for 275°F operational capability. This thrust has major impact on the life cycle policy goal and airlift systems development goals due to greater safety and reduced potential for system loss due to fires and on future fighter aircraft in performance needs.

Integral Fuel Tank Sealants

This thrust covers two major directions, one concerned with the reduction of O&S costs, the other with exploratory development of improved sealants.

O&S - This direction has the objective of developing

long life sealants, improved repair procedures and materials. Particular efforts include: development of new high adhesion sealants, verification of sealant life prediction techniques and sealant assessment in varying applications. Milestones involved in this work include: (1) development of a new high adhesion sealant to replace SOA sealants to reduce O&M costs, (2) develop an improved channel sealant for longer life operation, and (3) confirming that life prediction techniques are supported by data.

Fasil Development - The goal of this direction is to develop a low cost high performance broad temperature fuel tank sealant for -15°F to 450°F. Specific programs include sealant synthesis, curing agent and additive synthesis, and compounding and evaluation efforts. Major milestones involve: (1) deciding whether sealants can be reinjected at 0°F or if 40°F is feasible, (2) determining if the low cost filleting sealant is ready for flight testing, and (3) selecting a channel sealant for flight test.

The two directions under this thrust impact the policy goal on life cycle cost because of their high potential for reducing maintenance costs and development goals in bombers, and tactical aircraft systems, because of performance limitations.

Instrument Lubrication

The goals of this thrust are to develop synthetic oils and greases for a spectrum of instrument bearing applications. Specific programs include grease formulation and evaluation, synthetic hydrocarbon oil development, retainer material development, and lubricating oil bearing evaluation. Key decision points involve: (1) determining whether the synthetic hydrocarbon oil development will have adequate formulations for evaluation in bearings, and (2) deciding whether data is sufficient to provide specification information for the G-200 bearing. This thrust has major impact on the policy goal of life cycle cost savings due to high maintenance costs in present systems.

Aircraft Tires

This thrust has the objectives of increasing tire life through the use of cut/tear tread materials, developing 450°F bead capability for tires used in carbon brake equipped aircraft, and developing multiretreadable and FOD resistant tires with 450°F capability. Specific programs include bead material developments, Kevlar reinforced tire development, dynamic evaluations, and flight testing. Milestones include: (1) a decision on flight testing of experimental tires in aircraft using carbon brakes, and (2) assessment of landing index of experimental tires relative to state of the art tires. This thrust impacts the policy goal on life cycle costs in a significant manner as tires are a high maintenance cost item.

Polymers for Elastomer Materials

This thrust covers the technology of polymers for seal materials and sealant materials. The goals are to provide candidate elastomeric materials for seals used for high temperature fluid containment applications and to provide new high temperature polymers for development as fuel tank sealants. The work on seal materials is primarily concerned with providing hydrolytically and thermally stable fluorocarbon ether based elastomers with broader use temperature ranges than current state-of-the-art seal materials. The work on sealant materials is concerned with providing molecularly modified polymers for transition into both filleting and channel type sealant applications. The milestones involve: (1) development of the FASIL polymer system for both sealants and seals, (2) a decision for or against exploratory development on -65 to 600°F seal materials in light of the feasibility of the technical approaches and the reality of the requirements for 600°F elastomeric seals, (3) selection of a polymer for scale-up as a transparent material, and (4) assessment of the potential of synthesis approaches with respect to priorities for laser hardened materials.

Accelerated Life Prediction

The goals of this thrust are to develop a laboratory capability for the provision of accurate accelerated life test data for spacecraft bearings and lubricants, to provide continuous consultation to SAMSO, and to provide design data for consideration in future systems. Specific programs involve studies on lubricant film thickness, bearing cage instability, failure mode analysis, lubricant transfer, solid lubricant bearing wear rate mechanisms, and development of accelerated prediction methods. The key decision point involves deciding whether knowledge of failure mode analysis and data is sufficient to begin the program on developing life prediction techniques. This thrust has significant impact on improving satellite reliability for systems designed for missile attack information.

Fluids and Lubricant Technology

This thrust has the objective of providing a 600°F base fluid for use in gas turbine oil formulation studies and hydraulic fluid developments. Specific efforts include fluid development, fluid degradation studies, fluid-additive synthesis, wear characterization, thermochemical behavior studies, and time-dependent lubricant property investigations. The milestones involve: (1) determining the status of the degradation mechanism effort, and (2) deciding whether perfluoroalkylether fluids are available or whether a domestic US source is needed. The thrust is significant to development of advanced performance aircraft because of limitations in current engine oil and hydraulic fluid performance.

Lubrication Systems Analysis

This thrust has the objective of developing new oil analysis procedures and instrumentation, reducing the cost of the AF spectrographic oil analysis program (SOAP) and developing new engine wear diagnostics. Efforts include advanced wear metal analysis research, advanced engine trending, new concepts for oil analysis including colorometric procedures, and lubrication systems analysis. This thrust impacts life cycle cost goals by tracing engine overhaul and operational life needs.

RELATED EFFORTS:

Accelerated Life Prediction Technology - No other agency laboratory is developing any of these types of tests.

Fluids - Limited efforts in the hydraulic fluid area are being conducted by the Navy/AML and NASA-Lewis. The Navy program is a formulation effort to develop a -65°F to 400°F less flammable hydraulic fluid for future systems based on silicone type fluids. NASA is sponsoring a fluid synthesis and formulation program based on the C-ester fluids for high temperature use (-40°F to 500°F). Both of these facilities also have hydraulic loop facilities for which AFML has, upon request, provided them with developmental hydraulic fluids for their requirements studies.

Oils and Greases - Army/Frankford Arsenal and Navy/AML have some inhouse effort in oil and grease development though Air Force requirements far exceed the objectives of those organizations. There is no indication of any upgrading of their objective to provide useful input to Air Force goals.

Solid Lubricants - Both Navy/AML and NASA-Lewis have inhouse efforts in this area. The Navy work is primarily aimed at using conventional solid lubricants as alternates for devices that are currently liquid and grease lubricated. NASA-Lewis is looking for new constituent materials as potential solid lubricants, but do not carry the development to finished lubricants which can satisfy given requirements. NASA is currently evaluating molded graphite-polyimide composites for spherical/journal bearing applications. Additionally, they are pursuing nichrome -CaF_2- glass systems for 1200-1500°F solid lubricant (SPACE SHUTTLE) applications. If promising results emerge from these efforts, AFML would use them for potential Air Force applications.

Seals and Sealants - The Navy (NADC) has a program to evaluate improved high temperature channel integral fuel tank sealants and has provided AFML funds to support the hybrid fluorosilicone sealant development programs and obtain early samples. The Army (AMMRC) has, for the past few years, supported a program to develop phosphonitrillic fluoroelastomers

suitable for use as hydraulic seal materials. The Army and AFML currently have a cooperative effort to develop and evaluate hydraulic seal compounds for the -65°F to 325°F temperature range. The current PNF compounds are tender and give poor results in dynamic seal tests. NASA has a polyimide seal development program for use with MIL-H-83282 for the -65°F to 400°F temperature range designed for applications to the space shuttle requirements. Compared to elastomeric seals, the polyimide seals are initially very expensive and also expensive to engineer into a system requiring precision designs and hardware.

REQUIREMENTS:

Efforts under this TPO impact all aspects of Air Force operational systems, including aircraft, spacecraft, missiles, and ground equipment. The specific requirements are listed below:

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
1	TPG	Strategic Offense	Significant
2	TPG	Strategic Defense	Significant
3	TPG	Tactical Warfare	Significant
4	TPG	Airlift	Significant
5	TPG	Command, Control Communications	Significant
6	TPG	Reconnaissance, Intelligence	Significant
7	TPG	Policy Goals	Significant
8	TPG	Mission Support	Desirable
9	TPG	Technology Development	Significant
10	ASD TN 69-72	Improved High Temperature Explosion Suppression Materials for Aircraft Fuel Tanks and Dry Bay Areas	Significant
11	ASD TN 72-532	Temperature Resistant Materials for Aircraft Tires	Significant
12	ASD TN 75-31	Lubricant Shelf Life in Instrument Ball Bearing	Significant
13	ASD TN 74-34	Hydraulic System Seals	Significant
14	ASD TN 72-35	Non-Flammable Hydraulic Fluid for Future Hydraulic Systems	Significant
15	SAMSO TN 76-46	Boundary Lubricants for GYRO Gas Spin Bearings	Significant

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
16	SAMSO TN 76-04	Life Prediction of Lubricants for Space Systems	Significant
17	SAMSO TN 76-47	Surface Coating for GYRO Scope Gas Spin Bearing Parts	Significant
18	ASD TN 72-39	High Temperature O-Ring Seals for Advanced Fuel Systems	Significant
19	AFSC Development Goal SO-2	Penetrate Soviet Defenses	Significant
20	AFSC Development Goal SO-3	Destroy Objective Targets	Significant
21	AFSC Development Goal TW-4	Acquire Fixed Ground Targets	Desirable
22	AFSC Development Goal TW-6	Acquire Mobile Surface Targets	Desirable
23	AFSC Development Goal SD-1	Provide the information required to respond to a Missile Attack	Significant
24	AFSC Development Goal SD-6	Provide an Atmospheric Threat Interdiction Capability	Significant
25	AFSC Development Goal AL-1	To Airlift Unit Equipment and Personnel to areas where the US becomes engaged in a Conflict-Requirements for Europe are the most stringent	Desirable
26	AFSC Development Goal AL-2	To Provide Intra-Transportation for goods and personnel which is not provided by surface transportation	Significant

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
27	AFSC Policy Goal 1	Life Cycle Cost	Significant
28	AFSC Policy Goal 3	Energy	Significant
29	AFSC Development Goal SD-4	Provide a Space Defense System for U.S.	Desirable

AFML TPO-4 FLUIDS, LUBRICANT, AND ELASTOMERIC MATERIALS

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
HYDRAULIC FLUIDS	62102F 2421	228 3	308 2 △1	318 3	205 2	200 3	150 3	250 3 ▽ 1-4, 6-9, 14,&19-28
	78011F		200 1	△2	300 1 ▽			
FLUID SYSTEM SEALS	62102 F 2421	260 4	206/100 4 △1	210/100 4 △2	174 4	200 3	250 4	250 4
	78011F					500 1	▽ 1-4, 6-9, 13, 18 & 19-28	

AFML TPO-4 FLUIDS, LUBRICANT, AND ELASTOMERIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
INTEGRAL FUEL TANK SEALANTS O&S	62102F 2421	144 2	255 2 △1	205 1 △2	244 1	150 2 △3	150 2 ▽ 1-4, 6-9, 10,& 19-28	
	78011F			300 1	200 1 ▽ 1-4			
INTEGRAL FUEL TANK SEALANTS Fasil Development	62102F 2421	155 3	223 3 △1	272 3 △2	235 3 △3	200 3	250 2	400 3
	78011F						500 1	1000 2 ▽ 1-4, 6-9, 10,& 19-28

AFML TPO-4 FLUIDS, LUBRICANT, AND ELASTOMERIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
INSTRUMENT LUBRICATION	62102F 2421	106 2	100/100 2 1	125 2 2	78/50 2	100 2	200 2	200 2 1-9, 12, 15, 17 & 19-28
	78011F	250						
AIRCRAFT TIRES	62102F 2421	80 1	125 2		80	70 1-4, 6-9, 11, & 19-28		

AFML TPO-4 FLUIDS, LUBRICANT, AND ELASTOMERIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
POLYMERS FOR ELASTOMER MATERIALS	62102F	2421	297	139/100	220	190/50	300	300	300
			3	3	3	3	3	3	3
									1-4, 6-9, 10, 13, 18 & 19-28
	61101F	ILIR	100	100		100			100
ACCELERATED LIFE PREDICTION	62102F	2421	197	257	282	339	400/50	400/100	400/150
			6	6	6	6	6	5	4
					1				
	78011F							500	1500
								1	2
									2,7,9,16, 27 & 29

AFML TPO-4 FLUIDS, LUBRICANT, AND ELASTOMERIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
FLUIDS AND LUBRICANT TECHNOLOGY	61101F	ILIR			100				
	62102F	2421	253 3	207 3	168/100 3	355 3	430 3	300 3	300 3
									1-4, 6-9, 14 & 19-28
LUBRICATION SYSTEM ANALYSIS	61101F	ILIR					100	100	
	SA-ALC		(44)						
	62102F	2417	2	2	0/100 2	100/50 2	100/150 2	150/100 2	200/100 2
									1-4, 6-9, & 19-28

AFML TPO-4 FLUIDS, LUBRICANT, AND ELASTOMERIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
TOTALS:								
FUNDS								
61101F		100	100	100	100	100	100	100
62102F		1720	1820/300	1800/300	2000/150	2150/200	2150/200	2300/250
78011F		250	200	300	500	500	1000	2500
PE 62102F 06DS		1475	1500	1500	1525	1625	1750	1900
NON-ADD								
SA-ALC		(44)						
TOTAL TPO FUNDING		3589	3620/300	3700/300	4125/150	4375/200	5000/200	6800/250
MANPOWER								
S, E & T DIRECT MY		28	28	28	28	28	28	28

TECHNOLOGY PLANNING OBJECTIVE

TPO NUMBER 5 TITLE PROTECTIVE COATINGS AND MATERIALS

GENERAL OBJECTIVE AND INVESTMENT STRATEGY:

This TPO provides materials and concepts to enhance the survivability of aircrew and vital components of Air Force systems in natural and induced hostile environments. Although related to material needs discussed in other TPO's, materials considered here have as a primary concern a protective function that is essential to the survival of the crew, structure, avionics, and other critical sybsystems of the military systems. Materials efforts covered by this TPO are in the areas of laser hardened materials, protective coatings and materials, and munitions. The AFML is the AF lead laboratory for technology and advanced development in laser hardened materials. Current threat assessments reveal this to be a critically needed program. The overall objective is to develop, evaluate, and demonstrate laser hardened materials for all critical systems components to counter high energy laser threats. Coatings and materials for protection of aircraft and cruise missiles against nonlaser hostile environments (such as nuclear thermal flash, IR/visible detection, rain, dust, and corrosion), and for protection of satellites in the space environment (such as solar radiation, charged particles, and contamination) continue to be needed to increase the survivability as well as reduce high O&M costs of AF systems.

SPECIFIC GOALS AND TECHNICAL APPROACHES:

Laser Hardened Materials: The AFML laser hardened materials (LHM) program covers the spectrum of development from basic research (PE 61102F) through exploratory development (PE 62102F), advanced development (PE 63211F), and manufacturing technology (PE 78011F). Thrusts and major objectives of the program are Satellite Components, Aircraft Hardening, Sensor Missile Hardening, and Response and Evaluation of LHM.

Satellite Components:

Satellite laser hardening is critical to the survivability of current surveillance and communications satellite systems which provide the information to respond to a missile attack, are needed to control the nuclear capable forces, and provide crisis response capability (i.e. DSP, AFSATCOM, DMSP, GPS, and DSCS), and to systems which will be used in the future to provide information to respond to a bomber or bomber launched missile attack (i.e. a space based radar or a high altitude large optics satellite). The objective of this effort is to develop laser hardened satellite materials and components for

both near term (next five years) and longer term threat levels, under the contraints of the satellite mission, lifetime, space environment, and nuclear requirements. The near term satellite materials hardening (SMATH) program has already transitioned completely into advanced development and manufacturing technology. The longer term, higher threat level, SMATH program will begin the transition from exploratory to advanced development in late FY78. Emphasis is on optical, radio frequency, solar panel, attitude control, and thermal control components. Approaches under development include vanadium oxide and chalcogenide glass optical switches, rejection filters, fabric coatings and insulation blankets, silicon nitride cover glass, silica fabric substrates, and nonlinear thermal control coatings. Flight demonstrations of the near term threat level laser hardening concepts are projected to occur in FY80 and FY81.

Aircraft Hardening:

The trends in strategic bomber penetration - low altitude flight and high speed standoff missiles -- will force the Soviets to develop effective defensive weapons. It is likely that ground based and airborne high energy laser weapons will be among these defenses. Given this threat, it follows that the development of laser countermeasures that do not significantly compromise payload and performance will be essential to the future viability of the manned strategic bomber force. The possibility that laser weaponry developed for strategic defense will be adapted for use by tactical forces also has become a necessary consideration. Retrofitting existing strike aircraft and designing future strike systems with laser countermeasures is thus a foreseable future need. The aircraft LHM program is the only DOD effort addressing these needs and therefore is critical to future bomber penetration and tactical strike goals. The objectives of the program are to assess the vulnerability of aircraft structures to pulsed and CW lasers, develop hardened coatings for skins, prevent fuel system fires, develop barriers to protect critical internal components, and explore innovative concepts for hardening aircraft components. Approaches being undertaken include carbon loaded ballistic foam, ablative/reflective skin coatings, intercalated graphite barriers, silicone canopy layers, reflective and ablative radome coatings, sprayable internal barriers, and reinforced glass matrix radome materials. The major emphasis of the program remains that of hardening against CW laser threats.

Sensor and Missile Hardening:

Advanced Air Force air-to-air weaponry will be needed to eliminate airborne threats, and advanced air-to-ground weaponry will be needed to neutralize fixed and mobile surface targets. The trend in both air-to-air and air-to-ground munitions is toward

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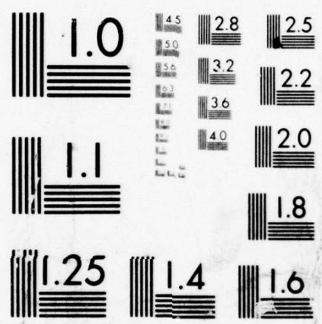

MICROCOPY RESOLUTION TEST CHART
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passive and semiactive electrooptical (EO) and active radio frequency (RF) systems. Though very effective, EO and RF imagers and seekers are unfortunately easily disabled by both in band and out of band radiation. Thus, any passive laser countermeasures technology that can be incorporated into EO and RF systems will have significant impact on their future effectiveness. The objectives of this thrust are to assess the vulnerability of sensor systems to in band and out of band lasers, both pulsed and CW, and to design, develop, and demonstrate hardening concepts. Approaches under development are the use of intrisically hard materials such as silicon nitride, silicon carbide, silica, and sapphire, reststrahlen reflection coatings, multilayer dielectric filters, optical switches, and advanced concepts based on electrostriction and nonlinear optical limiters. Demonstration of a hardened EO system will begin under an advanced development program in FY79. Demonstration of a hardened RF missile system will be undertaken in the FY82 time period.

Response and Evaluation of Laser Hardened Materials:

Technology support to provide laser hardened materials development guidance and to evaluate the performance of laser hardened materials will be continued through FY82. Approaches include testing under simulated operational conditions and the use of computer codes to analyze and predict the response of materials to laser heating.

Protective Coatings and Materials:

This area encompasses materials technology for satellites and aircraft. Thrusts and major objectives are Extended Life Satellite Materials, O&S Cost Reduction for Coatings, Visual/IR Camouflage Coatings, and P-static/Erosion Resistant Coatings.

Extended Life Satellite Materials:

Survivability of the surveillance and communications satellites that would provide the information needed to respond to a missile or bomber attack and to control the nuclear capable forces is a critical need. Environmental survivability, i.e. lifetime, is as vital as is survivability to hostile attack. This program addresses environmental problems that shorten the lifetimes of satellites. Goals are to determine electrical charging/discharging and contamination mechanisms and their effects on space materials, develop charge control approaches and materials to protect satellite surfaces from 0.1 - 30 kev electrons, develop conductive and transparent films for thermal control and optical surfaces, develop physically survivable thermal control materials with reduced IR and radar cross section, develop a satellite contamination vulnerability model,

and provide low contamination satellite materials. Chemical vapor deposited indium oxide is being investigated as a conductive coating for optical surfaces; sputtered indium and tin oxides on polymeric films are being developed as conductive thermal control surface coatings. For contamination control, the effects of film and particulate contamination will be studied, and low outgassing adhesives and potting compounds based on high molecular weight silicone and other polymeric systems are under development.

O&S Cost Reduction for Coatings:

This thrust provides significant contributions to AFSC goals to reduce operational and support costs and to reduce the environmental impact and health hazards of aircraft paint stripping, priming, and coating operations. Approaches to reducing O&S costs are airless electrostatic application techniques, polymeric bead pigments for durable cleanable coatings, and encapsulated corrosion inhibiting primers. Approaches to improving environmental and occupational safety include high solids coatings based on polyurethanes and water-based coatings with improved durability polymers.

Visual/IR Camouflage Coatings:

Low visibility of aircraft, their standoff missiles, and RPV's is a vital aspect of penetrating Soviet defenses, intercepting attacking bombers, establishing air superiority, attacking surface targets, and performing reconnaisance. The survivability of aircraft and RPV systems can be significantly enhanced by reducing the acquisition range of visible/IR activated defenses. The objective of this program is to develop a variety of visual/IR suppression coatings that provide tailored camouflage for a wide range of operational needs and which are compatible with other requirements, e.g. thermal flash and corrosion protection. A manufacturing scaleup program for a low visibility thermal flash resistant silicone paint is planned for FY80.

P-Static/Erosion Resistant Coatings:

Manned bombers and externally carried cruise missiles are required to be nuclear hardened against multiple bursts in order to assure launchability under all out nuclear attack. This program addresses the problem of protecting the aircraft and missile surfaces from nuclear thermal pulses, at the same time providing precipitation static and erosion resistance to nonconducting surfaces such as radomes and composite parts. Development will continue on a conductive, white, erosion resistant fluorocarbon elastomeric coating to provide simultaneous nuclear flash, rain erosion, and precipitation static protection for B-52, cruise missile, AABNCP, and other radomes. An interim solution black-over-white coating that provides

one-shot nuclear thermal protection has been applied to the B-1. A conductive gray coating has also been developed for the F-16 that provides rain erosion resistance and color matching. Conductive white metal oxide pigments are being developed as a longer term solution. Manufacturing scale-up is planned for FY80. The AFML Mach 1.2 and 3.0 rotating arm rigs will continue to be used to assess materials response to subsonic and supersonic erosion environments.

Munitions

The major objectives of this area are to provide on a production basis, munitions components (projectiles, warheads, cases, propellants, explosives) at substantial reductions in cost, and to develop materials and processes for air superiority weaponry having significantly improved lethality.

RELATED EFFORTS:

Within the Air Force, evaluation of the behavior of materials subjected to high power laser radiation is being done under the Advanced Radiation Technology Program at the AFWL. The development and analysis of radiation resistant materials and protective concepts is done in conjunction with efforts of the Advanced Radiation Technology Program. The Army and Navy have laser hardened materials programs addressing the protection of systems peculiar to their interests such as ground vehicles, helicopters, and personnel for the Army, and aircraft and missiles for the Navy. Coordination of the programs among the three services is accomplished through the DDR&E Laser Hardened Materials and Structures ad hoc panel.

The Navy Air Development Center is developing a rotating arm rain erosion simulation apparatus, and subsonic rain erosion testing of elastomeric coatings and reinforced composites is being conducted at a low level of effort by the Naval Air Systems Command.

Thermal control paint coatings for satellites are being developed by NASA. Efforts are directed toward the Space Shuttle. NASA does not treat the problem of laser hardening specifically, although NASA has provided canopy materials and some laser test support. Contamination of spacecraft thermal control coatings and optics is being studied by AFML, AFRPL, and SAMSO as well as by NASA Spacelab,and Space Shuttle contamination groups. This includes contractual efforts with industry and other organizations. A joint AF/NASA research and technology program in the area of spacecraft charging has been developed. The program consists of a combined contractual and inhouse effort aimed at understanding the charge phenomena, relating spaceflight data to ground tests results, and developing new or modified conductive materials. AFML is the lead

laboratory for these materials developments. The Army and Navy are both concerned with highly diffused, low reflectance infrared camouflage coatings for defending against ground-to-air IR guided missiles, but are not sponsoring programs in this area.

REQUIREMENTS:

This TPO supports a wide range of Air Force requirements. Among the more critical support provided are the extension of the lifetimes of U.S. satellite systems, protection of strategic bomber and satellite systems against nuclear and laser weapons, reduction of O&S costs of operational aircraft, and protection of tactical systems against ground-to-air IR seeking missiles.

Contamination of satellite thermal control and optical surfaces due to outgassing and electrostatic discharges due to space charge buildup are known to have caused premature loss of several satellites and to have led to degraded performance in many others. The space stable materials and conductive coatings being developed under this TPO have already had a significant impact on satellite life and provide confidence that the ultimate goal of 7-10 year satellite service life can be reached.

Providing strategic systems with hardness against high energy lasers is a difficult problem. However, intelligence estimates, as well as a mirror image projection of our own laser technology, require that laser hardening be considered a priority Air Force goal. Providing laser hardness without compromising systems performance dictates the use of passive countermeasures to the greatest extent possible, and this forms the driving function of the AFML laser hardened materials program. Viable materials hardening approaches have already been demonstrated for metallic structural skins, for canopies, and for satellite components, and materials solutions to the hardening of radomes, composite skins, and optical systems are being evaluated.

Improving the durability, strippability, applicability, and disposability of ordinary aircraft paint and primer coatings would have an impact on the costs of maintaining the flying AF well in excess of the investment in new materials development. For example, flexible primers with toughness and modulus equal to the polyurethane paint overcoats would quadruple the life expectancy of the coatings and lead to tens of millions of annual dollar savings in maintaining cargo aircraft alone.

REQUIREMENTS:

Requirement Identification Number	Requirement Number	Requirement Title	Lab Assessment of TPO Applicability
1	TPG	Strategic Offense	Critical
2	TPG	Strategic Defense	Critical
3	TPG	Airlift	Significant
4	TPG	Tactical Warfare	Needed
5	TPG	Command, Control, Communications	Significant
6	TPG	Reconnaissance, Intelligence	Significant
7	TPG	Life Cycle Cost	Needed
8	TPG	Environment	Significant
9	TPG	Technology Development	Significant
10	DG SO-1	Launch the Strategic Attack Force	Needed
11	DG SO-2	Penetrate Soviet Defenses	Critical
12	DG SD-1	Provide the Information Required to Respond to a Missile Attack	Critical
13	DG SD-5	Provide Information to Respond to a Bomber/Bomber Launched Missile Attack	Critical
14	DG SD-6	Provide an Atmospheric Threat Interdiction Capability	Needed
15	DG AL-1	Airlift Unit Equipment and Personnel	Needed
16	DG AL-2	Provide Intra-Theater Transportation	Needed

Requirement Identification Number	Requirement Number	Requirement Title	Lab Assessment of TPO Applicability
17	DG TW-2	Eliminate Airborne Threat	Critical
18	DG TW-3	Acquire Fixed Targets	Significant
19	DG TW-4	Neutralize Fixed Targets	Significant
20	DG TW-5	Acquire Mobile Surface Targets	Significant
21	DG TW-6	Neutralize Mobile Surface Targets	Significant
22	DG C^3-1	Control of Nuclear Capable Forces: Gather Information	Critical
23	DG C^3-2	Control of Nuclear Capable Forces: Get NCA Decisions to Commanders	Critical
24	DG C^3-5	Provide Crisis Response Capability: Gather Information	Critical
25	DG RI-1	Collection of Data and Information	Significant
26	PG-1	Life Cycle Cost Policy Goal	Significant
27	PG-4	Environment Policy Goal	Significant
28	TN-SAMSO-AFML-65-10	Low Vulnerability Thermal Control Coatings	Critical
29	TN-SAMSO-AFML-73-03	Sources and Mechanisms of Contamination of Thermal Control Surfaces	Critical
30	TN-SAMSO-AFML-74-25	Laser Hardening of Space System Materials	Critical

Requirement Identification Number	Requirement Number	Requirement Title	Lab Assessment of TPO Applicability
31	TN-SAMSO-AFML-75-18	Spacecraft Charge Suppressing Techniques	Critical
32	TN-SAMSO-AFCRL-74-33	Spacecraft Charging at Synchronous Altitudes	Significant
33	TN-SAMSO-AFWL-72-22	Laser Vulnerability Assessment	Significant
34	TN-ASD-AFML-1107-72-38-03	Materials Technology Considerations for Laser Countermeasures	Critical
35	TN-ASD-AFML-2005-77-09	Laser Protective Devices	Needed
36	TN-ADTC-AFML-1901-84-02	Thermoplastics for Ammunition	Needed
37	TN-AFFDL-AFML-72-18	Corrosion Inhibited Primers and/or Coupling Agents for Weldbonded Joints	Significant
38	ROC TAF 301-73	Advanced Tactical Fighter	Needed
39	ROC SAC 13-73	Advanced Strategic Air Launched Missile	Needed
40	ROC USAF 2-76	Survivable Satellite Communications	Significant
41		Space Systems Survivability Implementation Plan	Significant

AFML TPO-5 PROTECTIVE COATINGS AND MATERIALS

FUNDING (X1000)

EFFORT	PE	PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LASER HARDENED MATERIALS	61101E								
Satellite Components		DARPA	(57)	▽9					
	62102F	2422	120 1	190 1	300 1		0/220	0/250	0/350
						▽2,12, 22,23,24,	30,33,41		
	63211F	2100	2400 3	3050 4	3800 4	3000 4	3500 2	4000 2	3000 2
	78011F		250 1	700 1	1200 1	600 1	200		▽2,12,13 22,23,24, 30,33,40, 41
						▽	2,5,12,22, 33,40,41	23,24,30,	
Aircraft Hardening	62102F	2422	85 1	100 1	200/100 1	425 1	350 1	200	
					▽9				
	63211F	2100	1700 1	1800 1	1500 1	2000 1	1800 2	1300 2	500 2
						▽1,4,6	▽11, 33,	17,18,19, 34,38,39	20, 21,25,
	78011F			150	300	400	1700 2	2000 2	2500 1
						▽11,17,38			

AFML TPO-5 PROTECTIVE COATINGS AND MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE	PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
LASER HARDENED MATERIALS (Cont.) Sensor and Missile Hardening	61101F	ILIR	50	▽ 9	50	▽ 9	50	▽ 9	50
	62102F	2422	191 2	335 2	225/100 2	425/160 3	600 3	850 3	1150 4
	63211F	2100	1100 1	1150 1	700 2	1000 2	2000 3	3000 3	2800 3
						▽ 4,19, 21	▽ 4,17	19,21,35	▽ 1,11,39
	78011F				400 1	900 1	1000 1	1500 2	2000 2
Response and Evaluation of LHM	62102F	2422	110 8	110 9	175 9	250 9	300 9	300 9	400 9
	62203F					▽ 1,2, 4,9		▽	1,2,4,9
		AFAPL	(55)						

AFML TPO-5 PROTECTIVE COATINGS AND MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PROTECTIVE COATINGS AND MATERIALS	35119F SAMSO	(20)						
Extended Life Satellite Materials	61101F ILIR		100	▽9		50	▽9	
	62102F 2422	480 4	500/100 4	730 3	715/100 3	600 3	600 3	500 4
	63438F SAMSO	(142)	(70)	▽	2,5,12,13, 24,28,29,	22,23, 31,32,40	▽	
O & S Cost Reduction for Coatings	61101F ILIR	50	▽9		100	▽9		50
	62102F 2422	34 1	130 1	300/80 1	285 1	465 1	450 1	400 1
	64714F AFCEC	(35)		▽3;	7,8,15,16,	26,27,37		
					▽4,	18,19,20,	21	
	78011F	200						

AFML TPO-5 PROTECTIVE COATINGS AND MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PROTECTIVE COATINGS AND MATERIALS (Cont.)	61101F							
	ILIR			50	▽9		100	▽9
Visual/IR Camouflage Coatings	62102F	70	85	100	100	135	150	200
	2422	1	1	1	1	1	1	1
			▽4,17	▽3,16		▽2,14	▽1,11,39	
P-Static Erosion Resistant Coatings	62102F	285	190	130	100	100	100	
	2422	3	3	3	2	2	2	
	78011F				▽4,17 300	300 ▽1,10		

AFML TPO-5 PROTECTIVE COATINGS AND MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
MUNITIONS	61102F		(72)						
		AFATL							
	62102F		80	0/100		100/100	150	150	150
		2422	1			1	1	1	1
									36
	62602F			9					
			(11)						
		AFATL							
	64603F		(8)						
		ADTC							
	78011F		2500	1000	1000	1000	3200	3500	2500
			2	2	2	2	2	2	2
							14,17, 19,21		
			(75)						
		ARMY							

AFML TPO-5 PROTECTIVE COATINGS AND MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
TOTALS:								
FUNDS								
61101F		100	100	100	100	100	100	100
62102F		1455	1640/200	2160/280	2400/360	2700/220	2800/250	2800/350
63211F		5200	6000	6000	6000	7300	8300	6300
78011F		2950	1850	2900	3200	6400	7000	7000
PE 62102F 06DS		1425	1525	1500	1450	1545	1670	1800
Non-Add								
35119F		(20)						
61101E		(57)						
61102F		(72)						
62203F		(55)						
62602F		(11)						
63438F		(142)	(70)					
64603F		(8)						
64714F		(35)						
ARMY		(75)						
Total TPO Funding		11605	11185/200	12660/280	13150/360	18045/220	19870/250	18000/350
MANPOWER								
S, E & T Direct MY		30	31	32	32	32	32	32

TECHNOLOGY PLANNING OBJECTIVE

TPO NUMBER 6 | TITLE ELECTROMAGNETIC WINDOW AND ELECTRONIC MATERIALS

GENERAL OBJECTIVES AND INVESTMENT STRATEGY:

This TPO provides materials and manufacturing processes for optical, electromagnetic, and electronic subsystems. Major thrusts under way in this TPO are laser and infrared windows, detectors, radomes and antenna windows, packaging and interconnections, data processing and control, data presentation and memories, microwave devices, energy sources, and windshields and canopies. Window materials are critical to the operation of high energy airborne laser weapons. The AFML is responsible for providing the windows for the Airborne Laser Laboratory laser weapon demonstration (AFWL ADP 317J); future window materials technology will address both the ongoing needs of the ALL and those of the laser weapons that will eventually be developed. Improved IR windows and domes will be a significant factor in the effectiveness of a variety of air to air missile and tactical target acquisition and seeker systems, e.g., forward looking infrared systems, the Imaging Infrared Maverick, Pave Tack, and dual mode seekers. The prime AFML goal is improved weather erosion resistance with improved optical quality. Long wavelength IR detectors are vital to the capability to acquire and track man-made objects in space from a space platform. Mosaic staring sensor arrays will provide a step function increase in sensitivity, resolution, and real time data handling capacity for surveillance and meteorological satellite systems. Radome materials to be developed in the near future are critical to tactical offensive and defensive air superiority. These include broad band high temperature radomes for high performance antiradiaion missiles and millimeter wave radomes for all weather ground target acquisition. Manufacturing technology for reproducible volume production of radiation hardened processing and memory circuits will be emphasized over the next five years. These electronics are critically needed for the reliable long term operation of communication, surveillance, and weather satellites in the natural radiation environment of space as well as in transient radiation fields produced by enemy attack and for the survivability of strategic missiles during launch and penetration. The improved reliability of the electronic circuits to be produced will provide significant cost savings in the long run. Manufacturing technology is needed for low cost, reliable microwave components (traveling wave tubes, surface acoustic wave devices, filters, oscillators, and power transistors) for electronic countermeasures (ECM) radars and communications equipment. Advanced technology storage batteries and magnetically suspended reaction wheel assemblies will be manufactured for satellite applications. These will significantly impact the long term reliability and service life of power supplies and attitude control subsystems. Windshield and canopy materials development will concentrate on improving the optical quality and temperature limits of impact and abrasion resistant transparency constructions.

SPECIFIC GOALS AND TECHNICAL APPROACHES :

Infrared Windows: Advanced IR dome and window materials are needed for future generations of heat seeking missiles and imaging infrared systems. This program is presently addressing needs for increased spectral transmission (0.5 to 12 microns) for multispectral applications, and rain erosion resistance for all-weather use up to speeds of Mach 2. Low cost sapphire and/or spinel

domes and low cost finishing processes will be developed for a multispectral short range air-to-air-missile (SRAAM). Zinc sulfide on zinc selenide sandwich windows will be developed to combine the superior IR transmission of ZnSe with the superior rain erosion resistance of ZnS. A program for advanced materials and concepts for supersonic erosion resistance will start in FY 79. Modeling of materials response to erosion combined with experimental verification will continue toward the goal of predictable erosion behavior by FY 82. Advanced antireflection coatings that enhance rain erosion resistance will also be pursued.

Laser Windows: Under interlaboratory agreements, AFML is sole developer of material windows for high power airborne laser systems. The laser window program is heavily supported by the Advanced Radiation Technology Office of AFWL. The technology is critical to the future development of bomber defense and air superiority airborne laser weapon systems. The goals are development of very large (1/3 to 1 meter diameter), windows and coatings for high power laser wavelengths. Past emphasis was on the 10.6 micron CO_2 wavelength in support of the Airborne Laser Laboratory gas dynamic laser. Current and future efforts will concentrate on the 9.3 micron wavelength of the electro-aerodynamic CO_2 laser for the Short Range Applied Technology Program, and 3.8 micron wavelength region of the deuterium fluoride laser. For external windows, the previously developed zinc selenide will be adequate for both the 10.6 and 9.3 micron CO_2 lasers. By FY78, optimized three layer (TlI/KCl/TlI) antireflection coatings will have been developed, and size scaleup will have been completed. For internal windows at 10.6 and 9.3 microns, europium doped potassium chloride-rubidium chloride alloy has been chosen for scaleup and demonstration. This window development is scheduled to be completed by FY80. In the future, emphasis will shift increasingly to development and scaleup of alkaline earth fluoride window materials for DF laser applications. In the early planning stages is a joint DARPA/AFML program on mirror materials technology for high power HF/DF lasers.

Detectors: This program covers detector materials for infrared reconnaisance and surveillance systems, star sensor systems, laser guidance systems, and electrooptical systems for attack warning. For reconnaisance and surveillance, the objective is low cost detector arrays of mercury-cadmium telluride and doped silicon integrated with data processing electronics. HgCdTe is the superior material when background noise requires low temperature operation because of its intrinsically higher operating temperature compared to silicon for equivalent noise performance. A longer term approach to detector arrays for surveillance and reconnaiscance systems is planned for FY80. This approach-development of silicon-germanium alloys-promises to combine superior detector capability with the simpler silicon processing technology. Development of these materials technologies will produce significant advancement in the capabilities of missile and bomber attack warning staellites and of tactical target imaging systems. For guidance systems, current emphasis is on developing uniform, cost-effective GaP for satellite star sensors and on developing a domestic source of high purity Si detector materials for laser guided weapons. The GaP crystal growth technology will be transitioned to a manufacturing scaleup effort during FY79. Development of improved processing and characterization methods for extrinsic and intrinsic high purity silicon will start in FY78. The efforts on electrooptical attack warning systems emphasize longer life and lower life cycle costs for detector dewar packages.

Radomes and Antenna Windows: This thrust covers a variety of advanced materials development efforts on RF transparencies. In cooperation with AFATL and ADTC, a broadband radome for PAVE BRAZO and millimeter wave radome for the GBU-15 contrast seeker are under development. These new tactical missiles will significantly enhance AF capability for all weather strike against aircraft and fixed and mobile ground targets. Work on advanced ceramic radome materials for future supersonic strategic air launched cruise missiles and standoff air-to-air tactical missiles has begun. Work on antenna windows for a maneuvering reentry vehicle has concentrated on boron nitride/boron nitride composites. This work will be ready for transition to full scale development in FY79. This will assure availability of a critically needed component for the AMARV system that will be needed to assure penetrability and accuracy of reentry systems against future ABM defenses and hardened targets.

Packaging and Interconnections: Major objectives of work in this area are improved packaging of microlectronics, improved printed circuit boards, and reliable cables and connectors. Approaches such as plastic encapsulation and hermetic chip carrier packaging will minimize sources of electronic failure due to particle contamination. Electronic reliability is especially critical to the network of surveillance and communications satellites that would gather and distribute information in crisis situations. A number of efforts are aimed at increasing the yield and repairability and reducing the cost of PC boards. These efforts will receive increasing emphasis in the FY78-80 time period.

Data Processing and Control: The purpose of this area is to provide manufacturing methods to assure the producibility and lowest possible cost of data processing circuits for missiles, satellites, and aircraft. Specific goals are an order of magnitude increase in total gamma radiation tolerance in complementary metal-oxide-semiconductor (CMOS) integrated circuits for satellite processors by FY78, availability of radiation hardened bipolar circuits (sense amplifier, power transistor, and operational amplifier) for the MX guidance and other systems, a radiation hardened CMOS-on sapphire microcomputer circuit family for space and missile systems by FY80, and high speed microprocessor circuitory for C^3 applications for FY79. An effort to begin manufacturing methods development of gallium arsenide high speed integrated circuits is tentatively planned to begin in FY80.

Data Presentation and Memories: The objectives of this thrust are produci- and affordability of display systems, reliable solid state mass memories, and radiation hardened semiconductor memories. Typical of these manufacturing technology efforts are a high information rate display for F-111, multifunctional data displays for B-52 update, radiation hardened CMOS-on sapphire memory array, and metal-nitride-oxide-semiconductor on sapphire random access memory for MX, RV's and GPS.

Microwave Devices: The objective of this thrust is the producibility of low cost components for ECM and communications equipment. Component manufacturing programs currently underway are for a dual mode traveling wave tube (TWT) yttrium iron garnet (YIG) tuned oscillator, and YIG tuned filter for the F-15 and F-16 ECM systems and the ALQ-131; an I/J band amplifier and ECM integration technology for the F-15, ALQ-131 and ALQ-126 systems; and phase shifters for the electronically agile radar. Future programs are planned for GaAs field effect transistors, components for millimeter wave seekers, generic TWT amplifiers, and microwave integrated circuits.

Energy Sources: This thrust addresses the manufacturing of new technology and materials for aerospace power supplies. Objectives are higher energy density, higher efficiency, lower cost, and longer life for aircraft, missile, satellite, and life support power systems. Current programs involve manufacturing of fine filament Nb_3Sn superconductor wire in lengths to 3000 feet for high energy electrodynamic laser power supplies, nickel cadmium batteries, rare earth cobalt magnetically suspended reaction wheels for GPS, and temperature compensated permanent magnets for ultrastable inertial systems. Future planned programs include rare earth cobalt or superconductor airborne generators in the 2-20 megawatt range for laser power supplies, nickel hydrogen batteries for satellites, and rare earth cobalt permanent magnet flight actuators with electronic power control for flight testing in a fly by wire system.

Windshields and Canopies: The purpose of this thrust is to provide materials and processes for transparent enclosures for aircraft having inherent long life, impact and erosion resistance, high optical quality, high temperature capability, and compatibility with antistatic and anti-ice coatings. Work will continue on establishing processes to produce quantities of Polysac interlayer material for curing and characterization studies before beginning manufacturing scaleup. In FY78, an effort will be undertaken to synthesize and develop a new material having the optical and environmental capabilities of glass and the thermal stability and impact resistance of polycarbonate. Lower operational and maintenance costs will be addressed in FY79 by developing outer ply replacement techniques and new refurbishing procedures.

RELATED EFFORTS:

The scope of the electronics effort in government and industry is quite broad and directed toward numerous and varied objectives. At the research and exploratory development levels, research results may impact constructively on many areas of endeavor. Thus, there are many areas of related interest which must be monitored and integrated as appropriate. With respect to the R&D in electronic materials, excellent coordination is accomplished through the Advisory Group on Electron Devices (AGED) which reviews contractual and inhouse R&D activities of the Army, Navy, Air Force, DARPA,DNA, and NASA. Summaries of all actions coordinated by AGED are distributed widely and promptly. Coordination is also accomplished through meetings with Air Force product and user commands on specific areas of interest in electronic materials. Radiation hardening technology is coordinated through the Radiation Hardened Electronic Technology Coordinating Group (RHETCOG) which is made up of Air Force members from the research and technology laboratories as well as the product commands and centers. AFML has the lead laboratory role for laser window and infrared window materials and coating development. Promising laser window materials, coatings and fabrication process are identified to AFWL for engineering development. Supporting technology programs in DARPA and the Army and Navy are coordinated through the JTCG for TIS and Joint Panel on Night Vision Technology. The Navy effort in infrared transmitting materials is concerned with basic erosion phenomena through ONR, and surface quality requirements through NWC.

REQUIREMENTS:

The current and anticipated efforts of this TPO are designed to provide materials systems which result in lower LCC, enhanced capabilities, and/or new capabilities for operational and future systems. Laser and infrared window materials, advanced infrared detector materials, radome and antenna

window materials, exploratory development on microelectronic reliability, energy source materials -- all of these are specifically directed to achieving enhanced capabilities for command, control and communication, reconnaissance and surveillance, electronic warfare, navigation and guidance, target acquisition and tracking, information processing, etc. Underlying all of the current and anticipated efforts are such basic characteristics as efficiency, reliability, life cycle costs, and when appropriate, radiation hardening. These can be presumed to be the major driving forces behind these efforts in addition to consideration of achieving low weight and low volume in the electronic devices and components.

REQUIREMENTS:

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
1	TPG	Strategic Offense	Needed
2	TPG	Strategic Defense	Critical
3	TPG	Tactical Warfare	Significant
4	TPG	Command, Control, Communications	Significant
5	TPG	Reconnaissance and Intelligence	Needed
6	TPG	Life Cycle Costs	Significant
7	TPG	Technology Development	Significant
8	DG SO-2	Penetrate Soviet Defenses	Needed
9	DG SO-3	Destroy Objective Targets	Needed
10	DG SD-1	Provide the Information Required to Respond to a Missile Attack	Critical
11	DG SD-2	Provide Information to the NCA to Increase the Efficiency of Force Management	Needed
12	DG SD-3	Provide Information to Respond to an Attack on US Satellites	Needed
13	DG SD-4	Provide a Space Defense System for U.S.	Significant
14	DG SD-5	Provide Information to Respond to a Bomber/Bomber Launched Missile Attack	Significant
15	DG SD-6	Provide An Atmospheric Threat Interdiction Capability	Needed
16	DG TW-2	Eliminate Airborne Threat	Significant

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
17	DG TW-3	Acquire Fixed Ground Targets	Significant
18	DG TW-4	Neutralize Fixed Surface Targets	Significant
19	DG TW-5	Acquire Mobile Surface Targets	Significant
20	DG TW-6	Neutralize Mobile Surface Targets	Significant
21	DG C^3-1	Control of Nuclear Capable Forces: Gather Information for NCA Decisions, Compile and Present	Significant
22	DG C^3-2	Control of Nuclear Capable Forces: Get NCA Decisions to The Force Element Executing Commanders	Significant
23	DG C^3-5	Provide Crisis Response Capability: Gather Information for NCA/JCS Decisions, Compile and Present	Significant
24	DG RI-1	Collection of Data and Information	Needed
25	PG-1	Life Cycle Cost Policy Goal	Needed
26	TN-SAMSO-AFML-67-27	Advanced Antenna Window Systems	Significant
27	TN-SAMSO-AFML-76-05	Insulating Film Process for Electronic Piece Parts	Significant
28	TN-SAMSO-AFML-76-07	Plated Thru-Hole Continuity in Multilayer Boards	Significant
29	TN-SAMSO-AFML-76-21	Magnetically Suspended Bearings	Critical
30	TN-SAMSO-AFAL-69-08	Improved SWIR Detector Technology	Significant

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
31	TN-SAMSO-AFAL-70-07	Medium Capacity, Radiation Hardened Memory for Reentry Application	Significant
32	TN-SAMSO-AFAL-72-05	Integrated LWIR Detector/Preamplifier Arrays	Critical
33	TN-SAMSO-AFAL-72-16	MOS MSI Manufacturability and Environmental Assessment	Significant
34	TN-SAMSO-AFAL-74-02	Hardened Semiconductor Memory Devices	Critical
35	TN-SAMSO-AFAL-74-10	Photodetector Development for Star Sensors	Significant
36	TN-SAMSO-AFAL-74-45	Radiation Hardened CMOS Devices for Space	Significant
37	TN-SAMSO-AFAL-76-23	Hardened Logical Circuits	Significant
38	TN-SAMSO-AFAL-76-24	Spaceborne Computer and Memory Technology	Significant
39	TN-SAMSO-AFAL-76-25	Solid State Detector Array	Significant
40	TN-SAMSO-AFAL-76-50	Design Materials Development for Spaceborne TWTA	Needed
41	TN-SAMSO-AFAPL-76-20	Highly Efficient Power Generation	Significant
42	TN-ASD-AFML-1107-72-33-3	Laser Window Materials	Critical
43	TN-ASD-AFML-0401-77-11	Atmospheric Electricity, Aircraft Transparencies	Needed
44	TN-ESD-AFCRL-AFML-1702-75-17	HF Swept Spectrum Communications Development	Needed
45	TN-ADTC-AFML 1604-75-01	Radome Materials	Significant

Requirement Identification Number	Requirement Number	Requirement Title	TPO Applicability
46	TN-ADTC-AFML-1709-76-01	Missile Radome Development for Millimeter Wave Applications	Significant
47	TN-ADTC-AFML-0905-76-02	Integrated Circuit Technology	Needed
48	TN-AFAPL-AFML-1308-74-01	Manufacturing Methods for Multifilament Superconducting A-15 Compounds	Critical
49	TN-AFAPL-AFML-2013-14-08	Improvement of Minority Carrier Lifetime In Single Crystal Silicon	Significant
50	ROC-TAF-303-75	Short Range Air-to-Air Missile	Significant
51	ROC-TAF-310-75	Advanced Antiradiation Missile	Critical
52	ROC-TAF-315-75	All Weather Target Acquisition System	Significant
53	ROC-TAF-303-77	Air-to-Air Antiradiation Homing Weapon	Critical
54	ROC-ADC-6-73	DSP Near Term Improvement	Significant
55	ROC-ADC-1-75	An Improved Space Surviellance System	Significant
56	ROC-SAC-13-73	Advanced Strategic Air-Launched Missile Technology	Significant
57	ROC-USAF-10-75	Digital Nonsecure Voice Terminal	Needed
58	ROC-USAF-2-76	Survivable Satellite Communications	Significant
59	ROC-USAF-9-76	JSOR for Advanced Tactical Air-to-Air Missile	Significant
60	ADP 317J	Advanced Radiation Technology	Critical

AFML TPO-6 ELECTROMAGNETIC WINDOW AND ELECTRONIC MATERIALS

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
INFRARED WINDOWS	61101E	ILIR	100			100			100
	62102F	2423	240 2	600/100 2	515/150 2	525 2	825 3	500 3	500 4
	78011F				800 1	800 1		800 1	1400 1
						3,16, 50,59			1,5,8,9, 17,19,52, 56
LASER WINDOWS	61101E	DARPA	(22)						
	62102F	2423	400 4	370/100 2	325 1	300 1	385 1	340	300 1
	62601F	AFWL	(466) 3	(428) 3	(568) 3	(597) 3	(705) 3	(280) 3	
	63000F	AFWL	(522)	(280)	(250)	(220)			
	78011F		500 1	500 1	500 1		500 1	500 1	1000 1
						2,8,16, 42,60			2,8,13, 16,60

AFML TPO-6 ELECTROMAGNETIC WINDOW AND ELECTRONIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
DETECTORS	12431F	SAMSO	(40)						
	61101E	ILIR		100			100		
	62102F	2423	370 3	650 5	850 7	1000 6	700 5	700 5	700 6
					7,49		35,39		
	63428F	SAMSO	(30)						
	78011F		1400 2	1100 2	1200 2	1500 2	1800 2	2000 2	2500 2
					2,10,30		3,18,20	3,5,17, 19,24,25	2,10,12, 14,32,55
		ARMY	(18)						
RADOMES AND ANTENNA WINDOWS	62102F	2423	260 1	275 1	220 1	150 1	100/150 1	250/200 1	200/200 1
						7,56			
	62602F	AFATL	(45)						
	63601F	AFATL	(20)			1,8,26	3,16,45,51	53	3,18,20,46 56
	78011F					900 1	500 1	1000 1	1000 1

AFML TPO-6 ELECTROMAGNETIC WINDOW AND ELECTRONIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE	PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
PACKAGING AND INTERCONNECTIONS	62102F		180	105	300	300	330	400	500
		2423	1	1	1	1	1	1	1
					27,28				
	78011F		1200	2270	2300	2300	2500	2000	2000
			2	2	2	2	2	2	2
DATA PROCESSING AND CONTROL					6,	25,47	3,4,57	4,21,22,23	
	78011F		2000	1800	2150	2200	1500	2000	2200
			2	2	2	2	2	2	2
DATA PRESENTATION AND MEMORIES						1,	2,4,6,33,	36,37	
	78011F		1750	950	1900	2000	2000	2000	2200
			2	2	2	2	2	2	2
MICROWAVE DEVICES	33110F		3,	17,18,19,	20	1,2,4,8,	11,22,31,	34,38,44	
		SAMSO	(12)						
	62102F		100	0/200	100/100	100/100	160/200	260/250	500
		2423							
	78011F		2055	1650	1650	1800	1800	1500	1500
			2	2	2	2	2	2	2
				1,3,8,	16			4,6,21,22 23,40	
		NAVY	(350)						

AFML TPO-6 ELECTROMAGNETIC WINDOW AND ELECTRONIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT		FY77	FY78	FY79	FY80	FY81	FY82	FY83
ENERGY SOURCES	63401F	SAMSO	(156)						
	78011F		625 1	1020 1 48	29	1500 2	1400 2	1200 2 41	1200 2 29
WINDSHIELDS AND CANOPIES	61101F	ILIR			100			100	
	62102F	2423	10	100 2	200 2	325 2	500 1 6,7,25	500 1	300/300 1
	78011F		310 1	500 1	500 1 3,16		500 1	1000 1	1000 1 2,3,15,17, 19

AFML TPO-6 ELECTROMAGNETIC WINDOW AND ELECTRONIC MATERIALS (CONT.)

FUNDING (X1000)

EFFORT	PE PROJECT	FY77	FY78	FY79	FY80	FY81	FY82	FY83
TOTALS:								
FUNDS								
61101F		100	100	100	100	100	100	100
62102F		1560	2100/400	2510/250	2700/100	3000/350	2950/450	3000/500
78011F		9840	9790	11000	11500	12500	14000	16000
PE 62102F 06DS		1575	1525	1575	1625	1725	1850	2000
Non-Add								
12431F		(40)						
33110F		(12)						
61101E		(22)						
62601F		(466)	(428)	(568)	(597)	(705)	(280)	
62602F		(45)						
63000F		(522)	(280)	(250)	(220)			
63401F		(156)						
63428F		(30)						
63601F		(20)						
NAVY		(350)						
ARMY		(18)						
Total TPO Funding		14756	14223/400	16003/250	16742/100	18030/350	19180/450	21100/500
MANPOWER								
S, E & T Direct MY		27	29	30	30	30	30	30